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ON THE STUDY OF ANATOMY.[1]

By Lewellys F. Barker, M. B., *Tor.*

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With the advent of October, with its cool and bracing days and restful nights, there is regularly a quickening of activities in academic circles. The occupant of a professional chair, reinvigorated by temporary sojourn in forest or field, at the seaside or in the hills, resumes his teaching with renewed enthusiasm, and engages again in that original investigation which represents the most absorbing interest of his life. The student, too, perhaps, as yet less conscious of the actual need of an occasional remittance from his labors, has nevertheless had his holiday, and returns to the college of his choice ready for another season of diligent application and eager to begin once more the arduous tasks which the pursuit of knowledge entails.

It has long been customary in colleges in which medicine is taught to call a meeting of the faculty and students at the beginning of the autumn session. Such a meeting permits of the reunion of former teachers and students and the intro-

[1] An address delivered before the Faculty and students of Rush Medical College, October 5, 1900.

duction and welcoming of new teachers and new students. It gives, further, opportunity for the making of certain special remarks; and I have noticed that there is almost universally a tendency on the part of the faculty to grant the privilege of remark-making to some member of it who has lately been added to the staff. Being myself one of the most recent additions to an already large staff-family, the privilege has this year been gracefully allotted to me. However great a sacrifice on the part of my colleagues this may represent, I can assure you that the new-comer on this occasion, like the distinguished member of the faculty who last year addressed you, considers it a great favor to have the opportunity of expressing the pleasure he has in coming among you and being counted one of you, and to meet with an occasion on which he can more or less generally indicate the aims and scope of the science which he represents, and so publicly justify the position which he holds. Fortunately, in this latter respect the task is an easy one, for anatomy has in medicine long ago won its place as a science essential as a basis for all the subsequent medical studies, and moreover, my predecessors in office have been men of such sterling merit, power and inspiration, that the subject is here appreciated and reverenced. Especially true is this of him who has immediately preceded me as the occupant of the chair, and who has left it in order to accept a chair in surgery; while we commiserate anatomy on losing so able a representative, we must congratulate surgery on the enlistment in its service of so well trained and enthusiastic an anatomist. He has at this college developed, among other things, a course in surgical anatomy—easily one of the best given in America—and this part of the anatomical work, I am glad to assure you, he has promised, for the present at least, to retain. You join with me I know in wishing my colleague, Professor Bevan, a continuation of that success which he has already attained in the field of his ultimate choice.

The year in which we live marks an important epoch in the history of the college. Of a whole series of advances, I wish to call attention especially to one. Beginning with this autumn quarter, a closer relationship than has ever before existed between Rush Medical College and the University of Chicago has been established. Not entirely satisfied—for what true lover long is?—with that "sisterly" relationship which the term "affiliation" represents, the college has this year appointed to two of its fundamental chairs—physiology and anatomy—men who are already the occupants of chairs in the same sciences at the university. That such closer bond of union cannot fail to be of the greatest value, both for Rush Medical College and for the University of Chicago, I confidently believe. That it is only the forerunner of a still deeper intimacy, many, I am sure, both in the university and the college, fondly hope.

On thinking over anatomical subjects in the search for material for this address, the ideas which came to me grouped themselves in the main under two headings: (1) What does the science of anatomy include? and (2) How can the study of anatomy best be prosecuted? Each of these headings corresponds to matter enough for a single occasion; I have, therefore, decided to spend the time at my disposal this evening in a consideration of the former of the two questions, and to reserve for another time and place what I have gathered in answer to the latter.

Of the whole group of the natural sciences, there is perhaps no other member, the province of which is less well understood by the general public than is the science of anatomy. As ordinarily thought of by the layman, it is a science the study of which necessarily precedes the practical work of medicine and surgery; a science which is largely, if not wholly, descriptive, and one which to be mastered requires prolonged occupation, scalpel in hand and pipe in mouth, with dead and partially decomposed human beings. Such a view of the science, though perhaps not surprising when we recall the methods by which anatomy—so-called—has frequently in this and other countries been prosecuted, could, I do not need to tell you, be scarcely more widely removed from the truth. Anatomy is not simply a descriptive science; the study of it as a preparation for practical medicine and surgery represents only one side of its interest and usefulness; the scalpel is now perhaps the coarsest instrument it employs; its work is by no means confined to the human body alone, much less to the dead human body, and when it does deal with the latter, the material can be so well preserved that even the fragrant Havana is said to be more offensive to some sensitive souls than are the odors from the well kept preparation room.

Even medical men differ markedly in their conception of what anatomy includes, their ideas being based largely upon the kind of anatomy they themselves were taught, and upon the anatomical needs of the particular branch of medicine which, after graduation, they have cultivated.

Nor is there uniformity of opinion among the pure anatomists themselves, as can be readily seen by a perusal of the various addresses made by scientific anatomists in different parts of the world during the last twenty years. A free expression of opinion upon the subject has, however, gone far to make the aims and scope of the science clearer, until at present its principal representatives are more nearly in accord with regard to them than ever before.

In what this accordance consists, I can, I believe, make clearest to you by glancing briefly at the various steps through which the science has passed from the period when the earliest anatomical observations were recorded to the present day.*

* In the preparation of this address I have made free use of a large number of addresses made on similar occasions by other anatomists. I have had no hesitation in borrowing liberally as will be immediately apparent to those who are familiar with the bibliography. Especially useful to me have been the addresses and papers of His, Hertwig, von Kölliker, Macalister, Mall and Waldeyer. The following are some of the sources consulted:

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There can be no doubt that from the earliest times, curiosity concerning and interest in the make-up of the human body has existed. The references to man's body and its organization frequently to be met with in the pages of the old Hindu Vedas and of the earliest writings of all the Oriental nations make this evident. Nevertheless, the awe in which men stood before the human cadaver, together with the penalties threatened by religious leaders for its molestation appear to have effectually prevented any systematic examinations and the little knowledge possessed by the ancients, aside from the conclusions drawn from animals killed for food or for sacrifice, seems to have been drawn from the instances in which, through the violence of war, the chase, or of the natural elements, the human body became dismembered or eviscerated.

The earliest dissections of the human body of which no doubt exists are those which were undertaken at the Alexandrian School (B. C.) by Herophilus and Erasistratus, supported and protected by the intelligent Ptolemaic rulers. The name of Herophilus is still familiar to every beginner of anatomical studies in the term Torcular Herophili. The statement is made, though I hope it is not true, that these daring anatomists went so far, with Ptolemy's sanction, as to dissect living criminals, from which Tertullian designated Herophilus as *lanius* (Fleischer).

This opportunity for the anatomical investigation of the human body appears to have been unique, and it continued only for a short time. Even Galen's studies, the results of which were held for the following ten centuries at least to be infallible, were limited to the bodies of animals; he recommended, it may be remembered, the study of the bodies of apes and swine—the animals which in his opinion were nearest to human beings. After Galen, the natural horror which the examination of the dead body excites, together with the edicts of the church against dissection, prevented any further progress of descriptive human anatomy for a very long period. The church declared that Galen had been infallible, and that therefore no further anatomical studies were necessary. Fortunately for science, which knows but little infallibility, certain of its votaries in high favor at Rome gained permission, in the fourteenth century, to make dissections of human bodies, and to use them for demonstration before students. Mondini in Bologna again opened the path for scientific anatomical inquiry and started in Italy a movement which placed that country, as far as medicine is concerned, in the lead. Students from distant lands were at-

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tracted, as they always have been and always will be, to the point where progress was making the greatest headway.

The great Vesalius, often known as the father of anatomy, was among these wandering scientists. Born in Belgium and educated in France, he prosecuted his anatomical studies in Italy, especially when professor at Padua, to such a degree that he merits a place among the world's greatest reformers. This energetic, truth-seeking, idol-breaking, authority-denying man, dared to look at things as he saw them rather than as Galen had said that they should be, and thus made discoveries of the first importance in anatomy; by his artistic powers he rendered many of them imperishable; best of all, he broke forever the tyranny of tradition in anatomical knowledge, and threw wide open the gate by which men must always enter in the pursuit of anatomical truth. Vesalius was a contemporary of Luther; the year of his death is that of the birth of Galileo and of Shakespeare.

It was the spirit which animated Vesalius which later led William Harvey, the founder of physiology, to the discovery of the circulation of the blood, and Giovanni Battista Morgagni, the founder of pathology, to that mode of conception which Virchow has designated "the anatomical idea in medicine." It is the spirit which is embodied in every scientific worker of to-day who accepts the records of past investigation only as a guide—a guide which must be fallible since it is human—and which, therefore, must be repeatedly controlled; a guide which needs constant revision on account of the ever-increasing extension of the domain of sense, and one, which, if not added to significantly by the scientist in his lifetime, will stand as an everlasting witness to his inefficiency, a perpetual testimony to his lack of consequence.

Like all the natural sciences, anatomy in its earlier stages consists, of necessity, in the amassing in an empirical way of a store of naked facts. In other words, the subject is purely *descriptive* until a sufficient number of facts have been collected to make their arrangement and classification a task worth while. Adequate descriptions are based upon intelligent *observation*, which in turn is dependent upon the skillful use of the organs of sense, including the means which modern technique is ever inventing to extend them. The body is examined externally and internally in its various parts; it is looked at; it is felt. The size, shape, color, weight, consistence and reciprocal relations of the parts are noted; the results are recorded, the attempt being made to establish the material content of the science with all possible certainty, sharpness and clearness. The parts have first to be distinguished and named; then accurately described, their physical characters being established in language. The description of a natural object that shall call up in the mind of the reader a precise image of the object and that shall serve as a reliable guide to a succeeding observer, does not fall within the province of every man's capacity; happy indeed is the anatomist who possesses the power, for as has more than once been pointed out, an exact and clear description of the known is often of as great value as the so-called "discovery" in the region of the unknown.

The satisfactory naming of the various parts alone is a task of far greater difficulty than at first appears. An object must be studied for a long time, in many countries, and by men who know the relations of anatomy to every subject with which that science is allied, before a name for a part which shall be in accord with all the requirements can be decided upon. Almost every part has at various times received a series of names; periodical revisions of nomenclature by representative committees are accordingly desirable in order to arrive at uniformity among anatomists and to relieve the science of an immense number of names, since at best it must be grievously burdened.

Ever since the time of Vesalius there has been an unbroken series of anatomical observers who have devoted their powers to the attaining of skill in dissection and anatomical description. With energy and endurance and often at great personal sacrifice, this band of anatomists has developed this side of our science until it has reached the degree of precision which characterizes it to-day; a state indeed which many believe to be practically complete and incapable of further progress. Of the difficulties overcome by Americans in helping with this work since Mr. Giles Firman made the "first anatomy of the country," a good idea can be gained from the admirable historical review which we owe to E. M. Hartwell. While it is obvious that there must be a temporal limit to the discoveries which the naked eye is to make in anatomical fields, one has nevertheless only to refer to the current journals to see that the limit has not yet been reached. But the limits of progress in anatomical description will by no means be synchronous with those of macroscopic discovery of the objects themselves, indeed, considering the complexity of man's architecture and the different and ever-varying view-points whence descriptions are being written, it is scarcely conceivable that man will ever attain to descriptions which will be satisfactorily final. To the surgeon, to the artist, to the physiologist, to the scientific anatomist, the details of parts are of utterly different significance; the varying scale of anatomical values requires in each case a special description; an objective characterization of all details, merely as such, would make anatomical descriptions so ponderous and chaotic as to render them totally useless to any one. Nor can anatomical illustrations, in colors and otherwise, which are perhaps even more valuable than anatomical descriptions, ever be completely objective. The exact plates of anatomical objects which approach of late years ever nearer to that degree of accuracy which will permit of the taking from them of mathematical measurements, never attain actually to perfection; there must always be an element of subjectivity in them which may be inconsonant with the needs of some other observer at some other time.

Again, the greater or less degree of variability to which all parts of the animal body are subject, makes it difficult for anatomists to agree as to what shall be called normal, and thus the same object has frequently to be described in several different ways and multiply and exactly represented in pictures. There thus remains and ever will remain a task for

the anatomist in the domain of anatomical description and of anatomical illustration.

If it be true that in the fields just referred to there is still much work to be done, the statement is all the more justified with regard to the taking of measurements and weights of the body and its parts. The shape of the natural objects is nearly always such that the localization of fixed points whence measurements can be taken is rendered very difficult—so difficult that frequently the comparison of the measurements of one observer of an object with those of another observer of the same are useless. Again, owing to the variability of the bodily dimensions in the two sexes, in different races, at the various ages of life, according to individuality or under different physiological conditions, unless a whole series of data accompany a given measurement, the result may be of no value to a succeeding observer. In modern anthropology, however, definite criteria are always attended to and the measuring method is proving to be of the highest service in the elucidation of the questions that science has to solve.

The difficulties of anatomical measurement in large part obtain also when the weighing of anatomical objects is undertaken. Notable results have already been obtained, however, not the least of those in connection with the central nervous system being gained through the comparatively recent work of my colleague, Dr. Donaldson, in the university. The application of the method to the determination of the normal by Thoma may also be referred to as the beginning of a long series of investigations which, in the end can scarcely fail to be of the greatest importance. As His, who has discussed this and the foregoing subjects in an admirable manner, points out, it is difficult to imagine how the study of variations in constitution is to be approached unless this and similar methods are employed. As he says, it must be of decisive influence for the physiological capability of an individual, whether in his organization the musculature predominates over his nervous system, his epithelial tissues or his glandular organs, whether his heart is relatively large or small, whether accordingly it can increase the average blood pressure in the arteries to a great or to a slight degree, whether the man has a large or a small liver or whether he has a long or short alimentary canal. The study of anatomy with the unaided sense-organs is, as we have seen, one of no small magnitude, and one not yet completed. What then is to be said of that descriptive anatomy which invades the territory in which the eye only with the aid of the microscope can penetrate? The field of the microscopic anatomist is at least a thousand times wider than that of the macroscopic worker, and in that field, what has been said above concerning description, pictorial representation and anatomical measurement, equally holds good. It will yet be long ere the collection of microscopic data will have been completed. New methods open up new problems, and at present progress, descriptive and microscopic anatomy may probably occupy workers for centuries to come. Even with the methods and microscopes now at our disposal, we have entered a museum, the largest part of which has yet to be accurately catalogued, and who can say what new doors the methods and the microscopes of the century just before us are about to open up? The science of histography is almost as undeveloped as was geography before the voyage of Columbus. Between the histographic world of to-day and the architectural world of stereochemistry who will dare to prophesy what rich territories may exist?

The mere observation and registration of naked facts does not, however, satisfy for long the cravings of the investigating human intelligence. Indeed, there is something of a blunting character about the process if long continued without the synchronous operation of other faculties of the intellect. Man is a *classifying* and *generalizing* animal; there lies deep in his nature a desire to *arrange* the facts he observes in an orderly manner, with the object of *understanding* them. It is in the attempt to satisfy this human tendency that anatomy, instead of remaining a purely descriptive science, becomes elevated to a plane on a level with the other inductive sciences.

Evidences of attempts at anatomical classification are found among the earliest anatomists. The close resemblance of certain parts of one another soon gave rise to the idea of organic systems; such as the muscular system and the nervous system. The keen observations of Aristotle on the *partes similares* and the *partes dissimilares* may be recalled, as well as those of Fallopius outlined in his *Tractatus quinque de partibus similaribus*. It was left to the organizing brain of the young Frenchman, F. Xavier Bichat, to get a grasp for the first time of the relations of elementary *tissues* to the general architecture of the body. Although, through overwork and impecuniosity, his penetrating eyes were forever closed at the early age of about 30 years, Bichat left behind him three treatises—his "Traité des Membranes," his "Récherches physiologiques sur la vie et la mort," and his "Anatomie générale"—a legacy so immense that we cannot help lamenting with wondering regret the too early arrest of his labors. He recognized the fact that whereas in chemistry the more complex bodies are composed of simple elements, so in the architecture of man's body, simple *tissues* are variously combined to form the complex mixture of tissues which are ordinarily known as organs. He distinguished some 21 *systems* or *tissues*—the cellular, the osseous, the fibrous, the cartilaginous, the nervous, the muscular, the medullary, etc., basing his classification on the manner in which each tissue behaves in the presence of various reagents, the physical and vital properties of each and, finally, the character of each when met with under diseased conditions. In other words, Bichat was the founder of the modern science of *histology*, or, as it is sometimes designated, "*General Anatomy*."[3]

Before following the progress of anatomy further along this line, a word must be said concerning what must be regarded perhaps as the first direction taken by the investigat-

[3] Cf. Duval, M.: L'Anatomie générale et son histoire. Rev. Scient. Paris, 1886, xxxvii, 65, 107.

ing mind toward the *understanding* of organic forms—namely, the physiological (in its first stages, the purely teleological).

As has long since been pointed out, the language of anatomy is sufficient evidence of the long existence of the teleological conception in this science. For thousands of years the individual parts of the body have been known as "organs," and the processes going on in them as "functions." Just as function was unthinkable without a corresponding organ, so an organ without function was inconceivable, and thus wherever, in the series of well-understood parts of the body, one remains over whose purposeful participation in the processes of life is not understood, towards this is directed over and over again the mental acumen of the investigator to assign to the reluctant organ a definite significance.[4] It is not my purpose here to enter into a discussion of teleology. The world has been widely enough explored to utterly dispose of that gross anthropomorphic form of teleology which pointed to a humanly scheming architect of the universe, and whether or not we accept some more correct form of teleology is, at present, matter for individual opinion. This much is certain, that while no teleological view of nature actually *explains* the organization of a human body, the teleological conception has been particularly heuristic in its effects in the investigation of the relation between the physical processes in, and the physical characters of, the various parts of the body. Ever since Galen, though animated by a false teleology, wrote his *De usu partium*, in which the size, position, number, consistence and structure of the various parts are treated as facts which can be understood only through the investigation of the purposes which they subserve, this mode of consideration has been among the most influential. Even to-day a large part of the profitable research undertaken by anatomists, physiologists and pathologists, has for its aim the elucidation of the relation of structure to function, especially in microscopic domains. The work done in Ludwig's laboratory was largely of this nature, and as recently as 1883, H. v. Meyer[5] has asserted that the only possible way of understanding the organs is to proceed to the study of them from the physiological view-point. But if this were true, then all scientific anatomy would be physiology, a statement which narrow-minded physiologists might applaud, but which broader men know to be untrue. Physiology is one of the daughters of anatomy, and is not likely so soon to forget the fifth commandment. Johannes Müller was the last great scientist who covered both fields of anatomy and physiology; since his time investigators have cultivated one of the two at the expense of the other, a division of labor which we must recognize on the whole as beneficial, though that it is accompanied by certain drawbacks must also be confessed. Especially difficult is it to sharply separate the study of structure from that of function in the science of cytology, founded by Schleiden and Schwann, pupils of Johannes Müller in the fourth decade of this century. The development of the cell-doctrine, modified as it was somewhat later by the introduction of the protoplasm-theory by Max Schultze, marks a most important epoch in the history of both anatomy and physiology. Its value for the more practical side of medicine is sufficiently in evidence when one of its direct outgrowths, the cellular pathology of Rudolph Virchow, is recalled. The appalling elaboration of technical methods during the last few years has led to the accumulation of cytographic data which remove all the comfort we once had in looking upon the cells as elementary structures. Though cytophysiology is as yet far behind cytography in its state of development, there no longer remains any doubt that in approaching the cell we stand before an organism of enormous complexity of constitution, endowed with functional activities which must for long remain to us unfathomable. Any one who has worked much with protoplasm and nucleus, with archiplasm and centrosome, with cell-fibrils and cell-granules under various physiological conditions, cannot fail to appreciate the fact that here only the threshold of inquiry has been crossed—the exploration of the real nature of the cell only just begun. Indeed the evidence is fast accumulating in favor of the opinion that many of these morphonuclear cell constituents represent precipitates due to the action of reagents, and the laws governing their regular appearance under definite conditions are being investigated. It is exactly in these studies that structural and functional investigation still do well to go hand in hand, a fact which a survey of the cytological handbooks, now becoming so numerous, will show, is meeting with general recognition. I believe it was Du Bois Reymond who ventured the statement that "an ocean steamer with all its machinery and intricacies of construction is far less complicated in its composition than a cell." Would that the cell were no more complicated than the ocean steamer in construction!—the modern investigator would then soon be ready with the solution of its problems. Alas! the difficulties are not confined to the study of these organisms as individuals; already we have entered upon the investigation of their social relations, and cell-altruism and cell-egoism, cell-states and revolutionary cells are discussed as actively among cytologists as are the similar social questions concerning organic individuals of another order by the people at large. Further, in cytophysics and cytochemistry, research is at present most active—these subjects representing one of the most interesting subdivisions of recent physiology. Should the gulf between the present microscopic picture of the cell and its chemical structure ever be bridged, stereochemistry would enter into the domain of anatomy. So much in general, with regard to the physiological view-point in anatomy.

Closely allied to the foregoing, and in reality an offshoot from it, is the mode of consideration of the surgical and topographical anatomist. In this branch, the individual regions and cavities of the body are dealt with with regard to the reciprocal position of the various organs and systems. Surgical anatomy studies these relations only in so far as they are of importance in operative procedures; topographical an-

[4] Cf. His, W.: Ueber die Bedeutung der Entwickelungsgeschichte für die Auffassung der Organische. Natur. Leipzig, 1870.

[5] v. Meyer, H.: Stellung und Aufgabe der Anatomie in der Gegenwart. Biol. Centralbl., 1883, No. 12.

atomy, a wider subject, studies the relations mentioned and independently of their significance to the surgeon. The various regions of the body are studied sometimes in layers, sometimes with regard to serial clues to a particular structure. Sections of frozen cadavers have here proved to be of great value for the study of relations and for helping the student to make mental reconstructions of the parts analyzed by dissection. Surgical and topographical anatomy are thus seen to be subjects of very high practical importance—the former especially for the surgeon, the latter also for the worker in internal medicine. It is this kind of anatomy which has been brought to so high a state of cultivation in Great Britain, and especially in London, where most of the anatomy has been taught by men in surgical practice. Valuable as such instruction is for surgery and medicine, it should not be forgotten that it is applied anatomy rather than anatomy proper, and no less a scientist than Macalister has deplored the lack of advances in anatomy in England, attributing it largely to the one-sided mode of instruction in vogue, and to the examinations, to the passing of which the teaching is in large part directed. Surely certain morphological considerations are as important for the student of anatomy as the learning by heart of the various relations of an artery, especially if the student is not to become a surgeon; it would be melancholy indeed if there were not at least some members of the anatomical classes who regard the study of the architecture of the brain and spinal cord as interesting and as important as that of the perineum.

But anatomy as a science would never have attained to the dignified position it now holds had the minds engaged with it remained satisfied, after observing and registering its material content, with attempting the explanation of the human body from the physiological view-point or by exhausting the possibilities of its relation to the surgeon's knife.

As in the other natural sciences, the causality-need of the intelligence has forced the anatomist to undertake the investigation of the *origin* of the organic forms which he studies, and of the relations of these forms to other similar and dissimilar organic forms accessible to examination. In other words, the comparative and the genetic methods of study have been resorted to. Comparative anatomy and embryology together constitute morphology, at least in the sense in which the term is ordinarily used, and in morphology we recognize the part of anatomy which makes it truly worthy of being designated a science.

In the application of the comparative method, not only are the different parts of the human body compared with one another—the arms with the legs, the brain with the spinal cord, the skull with the vertebral column, the various segments and segmental partitions with one another—but man, recognized as a member of a long series of *animals*, is compared with each of them in turn, and they with one another, with the object of establishing groups of type forms and of learning the plan of architecture, not only of the single creature, but also of the whole series. At first, anatomists studied the forms which to them seemed to resemble man most closely, but the gradual transition from one form to another was so striking that animal after animal was studied until finally the whole world of organisms has been submitted to the examination of the comparative investigator. Oken and Goethe, Cuvier, Meckel, Geoffroy, St. Hilaire, Lamarck, Wallace, Darwin, Haeckel, Huxley, Gegenbaur and Leidy are names which have become very familiar to us in this field. The world of living creatures is a unitary system, of which man is an inseparable portion. First, when the whole system has been worked through do the form and significance of many of man's parts become intelligible. The animal series can be thought of as a tree with the simplest forms at the root, the trunk branching at its origin, each branch in turn subdividing into limbs and twigs until the highest degree of differentiation is reached. It is this recognition of the lawful relation of organisms to one another which the study of comparative anatomy has afforded us. Such a recognition, now general, was little less than startling to those who first arrived at it. That it pointed to some more general law was obvious. As Goethe himself, no mean participator in comparative studies, beautifully expressed it:

> "Alle Gestalten sind ähnlich und Keine gleichet der anderm,
> Und so deutet das chor auf ein geheimes Gesetz."

Has this secret law been discovered? Many believe so and look upon Darwin's doctrine of descent as a generalization worthy, on account of its scientific value, of being placed side by side with Newton's theory of gravitation. Whether the evolutionary doctrine be unequivocally accepted or not, certain it is that the relationship of forms which comparative anatomy reveals, finds in this genealogical conception of Darwin a more satisfactory explanation than any other hitherto offered.

Closely allied to the phylogenetic mode of consideration is that which we designate as the embryological ontogenetic or developmental. In the human species, as in every other, the life of the individual member is of short duration; each human organism has a beginning, a period of growth and development, followed, even in the life of maximum length, in the course of a few decades, by decline and death. Generation follows generation as wave follows wave on the surface of a ruffled sea. In the transference of life from one generation to another the material substratum sinks to a minimal amount—the new human being begins as a fertilized egg-cell 1-120 of an inch in diameter, weighing only a minute fraction of a gramme. From this simplest of beginnings it gradually passes through a long series of developmental stages, the character of these stages varying somewhat under environmental influences, each stage being the nnecessary consequent of a preceding stage, and at the same time the necessary antecedent of the stage which follows it until finally the organism attains to the fullness of differentiation of which, under the circumstances of its environment, it is capable.

In this long series of developmental stages which every mammal passes through, the earliest are very, very simple and correspond in form closely with the lower forms in the animal kingdom. But as cell-division in the embryo proceeds, the

shaping of the organism becomes more complex, resembling higher and higher forms of animal life, until finally that of mammals is assumed. Even at this period the unskilled observer might easily be confused if he were required at a glance to distinguish a human embryo from those of several other mammals at a similar period of development. Ultimately, the differential characters of the species become clearly marked, and even the tyro can easily recognize them. The more skilled the observer, however, the earlier in the development will the species-criteria be decisive.

Comparative embryology becomes all the more astonishing a study when we realize that the embryological history of every higher animal is, for a long period at least, almost identical with that of a whole series of allied forms. No wonder, then, this state of things being acknowledged, that the embryologists, like the comparative anatomists, have pictured the genetic relations of the different animal forms also as a tree, a tree which on close examination is found to accord very closely with the tree of relationship constructed by the comparative anatomists.

Comparative anatomy and embryology are, therefore, closely interwoven subjects, and each may, in a way, be looked upon as a control for the other, though each has its special problems, and each sets about the solution of these in a manner peculiar to itself. Take, for example, the attempts at an explanation of the series of forms through which the individual passes in its development. Many comparative anatomists, accepting Darwin's doctrine of the origin of species through a struggle for existence among generations influenced by heredity and variation, would explain the development of the individual member of a species as a temporarily compressed recapitulation of the developmental course of the species as a whole. While this doctrine that "ontogeny repeats phylogeny" has been maintained by eminent scientists there are others who are unwilling to accept what cannot be proved; and some of the embryologists especially feel it their province to attempt to explain from embryological studies alone, and without reference to phylogenetic history, the origin of the various form-stages through which the individual passes. Already great strides have been made in the direction mentioned, especially through the investigation of the laws of growth; and the field of developmental mechanics, though so lately entered upon, has proven to be one of the most fruitful of those thus far tilled. One of the foremost investigators along these lines goes so far as to assert that the growth of every organic germ must, as a process strictly regulated according to time and space, possess a mathematical expression in which the velocity of growth of each point is determined in its dependence on the time and the position. Whether such formulæ will ever be set up and the kingdom of organic forms thus subordinated to the domination of simple numbers, seems doubtful, but in any case the conception is an interesting one. We need not, however, look into the nebulous distance for the advantages to accrue from developmental study. Near at hand are thousands of facts of the greatest importance for anatomy as a whole and for the practical branches of medicine and surgery to be gained only through this method of study. Scarcely a part of the body but what is now better understood than was otherwise possible. I need only mention the remarkably complicated morphology of the brain and the sense organs, the distribution of the intestines, the grouping of the various voluntary muscles, the puzzling course followed by certain of the nerves and of the reproductive organs in the two sexes, to call to mind some of the features which embryology has gone far to illuminate.

I dare not pass by unnoticed here two phases of investigation which naturally follow upon the others, but which have only very recently begun to be extensively cultivated, viz.: those of histogenesis and of comparative histology. Histogenesis stands in the same relation to comparative histology as does embryology to comparative anatomy. Indeed, it is simply pushing the microscope into embryology and comparative anatomy, and is, in a way, comparable to the advance from gross descriptive anatomy to microscopic anatomy. By histogenesis we mean the study of the development of the individual tissues, including that of the individual cells (cytogenesis). By comparative histology and cytology we refer to the comparative microscopic study of the various tissues and cells through a series of animals. The light thrown upon many of the unsolved problems of structure by these methods is unexpectedly brilliant, and the future has much to hope from it; MacCallum, too, has shown how important these methods can be in helping to explain certain pathological phenomena met with in heart-muscle, and there can be little doubt that we are on the brink of the discovery of a series of relations between histogenetic conditions and pathological processes.

Lastly, as a crowning piece to the whole system of anatomical study, experimental morphology must be recognized. As but a child among the kindred sciences, it is of robust constitution, being the offspring of vigorous parents, and, in this country especially, in an environment most suitable for its healthy growth. The anatomist is no longer confined to the study of adult forms, or of forms in their natural mode of development; he can now, to a certain extent, artificially control form-production by resorting to the experimental method. The experiments which have been made upon heteromorphism, upon the artificial production of malformations, and upon the grafting of embryos, are full of interest, so much so as to disturb the equanimity of the soberest of scientists. During the last year or two we have been—I was going to say—shocked by the bringing of the proof by my colleague, Professor Loeb, that the eggs of several forms not naturally parthenogenetic can be fertilized—or at any rate, brought to development in the absence of spermatozoa, solely through the action of (?) physico-chemical influences. With miracles such as these already performed, we can but stand in awe of the work of the future.

Most sketchily and imperfectly I have tried to give you an idea of what the study of anatomy includes, viz.: descriptive or systematic anatomy (gross and microscopic), physiological

anatomy, surgical and topographical anatomy, histology or general anatomy, including histography and cytology, comparative anatomy, embryology, comparative histology and embryology, histogenesis and lastly experimental morphology. Assuredly the subject is wide. It is, I am sorry to say, too wide to be mastered in all its details even when a whole lifetime is devoted exclusively to it. The scientific anatomist, after familiarizing himself with the main facts and principles of its various subdivisions, does best, in agreement with the great law of division of labor, to direct his efforts towards the acquisition and promulgation of knowledge in some one portion of it.

And now for a word of welcome to the class just entering upon the study of medicine. You have taken, gentlemen, the first direct step which is to lead you into one of the noblest professions in the world—into a profession in which your lives are to be consecrated to the service of suffering men and women. You have to learn the laws which govern health and those which underlie disease. You, like your predecessors, will find that a large proportion of your time and energy in life will be directed toward the prevention of the occurrence of disease, rather than to the cure of it, for medical men have the proud distinction of being perhaps the only workmen "who make it their first duty to stop the sources of supply from which they derive their income." Hard work during the next four years will be required of every one of you; indeed, your time will be so occupied and your mental powers so strenuously engaged that you will have but little opportunity for recreation or for the amenities of life. But while this is the most difficult period of your career as far as intellectual work is concerned, do not, I beg of you, forget altogether the *man* in the making of the physician or surgeon. However much your instructors may stimulate you, however much work they may ask you to do, you will be wise if you retain some period of the day, be it only half an hour or even less, when you can withdraw from men and medicine and in some quiet nook indulge a wholesome longing for good general literature. Keep your old friends by you—your Plato and Marcus Aurelius, your Emerson, Carlyle, your Dante, Shakespeare and Milton, your Goethe, Shelley and Keats. If your osteological studies prove refractory you may find the stoicism of Epictetus a remedy for your disturbed spirit; after the depressive influences of pathological anatomy the lyric of Goethe, the raptures of Shelley, or an essay of Stevenson may prove to be uplifting; to combat the intoxicating fumes of the chemical laboratory try the antidotal effects of Burton, of Sterne or of Rabelais. The time so spent will not only be revivifying for the moment, but will be of the greatest value to you in your professional life after graduation. Skill is more and more reverenced, but skill without culture has lost half its power. And culture, like reputation, has not only to be gained but to be kept, nor is it gained or kept without effort, without constant vigilance.

Permit me to hope that you have laid broad foundations in the sciences which are fundamental for medicine; viz.: physics, chemistry and biology. Without thorough training in these it is impossible to keep abreast of the rapidly swelling tide of discovery in modern medicine. If, further, you are familiar with the French and German languages you will find it possible to become conversant with important new facts and discoveries months and sometimes years before they enter into the English text-books. Of the distinctly medical sciences, anatomy, physiology and physiological chemistry, together with pathology, form the framework upon which all the rest of the medical sciences are built. Failure to make this framework solid renders the superstructure inevitably unsafe. Do not forget that the medicine of to-day differs from that of the years close behind us chiefly in the substitution of "handcraft" for much of the former "headcraft." In these days, too, as it has well been put: "The eye cannot say unto the head, I have no need of thee." Instead of accepting the statements of others about things as of yore, the medical student is nowadays being made to *do* things. Instead of memorizing text-books, quiz compends and lecture notes, he is more and more required to study the natural objects, to observe accurately, to record concisely and adequately, to experiment intelligently. While good lectures, good recitations and good text-books still have their place, the student is wisely encouraged to interrogate Nature for himself and to believe in the replies he obtains from her rather than to put implicit confidence in the descriptions of others.

The new methods of medical education are costly; they demand large laboratories, expensive equipment and scientifically trained instructors. They cannot be satisfactorily introduced into schools where the sole income is derived from the fees of students; large endowments are absolutely essential for the proper carrying out of the plan.

Finally, gentlemen, let me give expression to the hope that among this class now entering, besides the large number who will go on into beneficent and successful practice, there may be some who, willing to scorn delights, to live laborious days, will set before them the high hope of making actual additions to knowledge. It is not fair that we should accept the gifts of our forerunners without making the effort ourselves to enrich the general stock of knowledge. The paths of investigation are not smooth; the way of research is difficult. But the goal is strife-worthy, and the rewards are sufficient.

In closing then let me quote those stirring words of the sage of Chelsea, which I excerpt from his Sartor Resartus.

"Produce! Produce! Were it but the pitifulest infinitesimal fraction of a Product, produce it in God's name! 'Tis the utmost thou hast in thee: out with it then. Up, up! Whatsoever thy hand findeth to do, do it with thy whole might. Work while it is called To-day, for the night cometh, wherein no man can work!"

ON THE OCCURRENCE OF TAILS IN MAN, WITH A DESCRIPTION OF THE CASE REPORTED BY DR. WATSON.

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Some years ago Bartels[1] gave an excellent *resumé* of our knowledge and beliefs concerning the occurrence of caudal appendages in man, showing that references to this peculiarity are to be found as far back as the writings of Pliny and Pausanias. Appended to Bartels' paper is a map, which shows the various lands supposed at one time or other to have been the haunts of human races with tails. These regions include not only widely distant portions of South America, Asia and Africa, but also the greater part of western Europe. While many of the statements cited by Bartels are to be classed as legendary, it is of interest to note how persistent and wide in range the belief in the existence of such races has been. The most remarkable stories have been told and have found credence; in these the significance of the caudal appendages has been variously interpreted. On the one hand, a tail has been considered a distinction of the highest degree, even a mark of divine descent, as in the case of the Ranas of Poorbunder;[2] on the other hand, it has usually been looked upon as a curse or a stigma of degradation.[3]

While careful investigation of the many travellers' stories has invariably given negative results regarding the existence of tailed races, so many individual instances of *homo caudatus* have been observed, that the popular belief in them has been kept alive without difficulty. With the growing interest shown by anatomists and anthropologists in the subject, the number of cases which have been reported has become considerable, and the fact that the human embryo at a certain period of development is provided with a tail-like appendage has lent color to the discussion of the question. Bartels in 1884 referred to one hundred and sixteen persons who had recorded observations upon tailed men. Of these, over sixty cases had been more or less completely described. In 1892 Schaeffer[4] collected additional cases, adding in all twenty-five. Pyatnitski[5] has also given an elaborate account of the subject, and still more recently Kohlbrugge,[6] in connection with an admirable description of a very interesting case, has made valuable comparisons with previous work. From the United States five cases have, to my knowledge, been reported.[7]

Undoubtedly we have in these so-called tails a most heterogeneous collection of anomalies. Anything appended to the sacral or coccygeal region is described as a tail. Many do actually bear certain resemblances to the tails of lower animals, and have in fact been compared with a great variety of these. On the other hand, some are vesicular or of irregular shape and accompany the condition of *spina bifida*, while others are to be classed as teratomata or other tumors. A further very significant fact is that a large proportion of the cases have been complicated by the coexistence of *ectopia viscerum*, *hypospadia*, *atresia ani*, or deformities of the limbs, all of which are known to result from amniotic adhesions. This circumstance has led Schaeffer to the conclusion that human caudal appendages are always due to this cause.[8]

There are, however, a great many cases in which the anatomical relations of the tail are such as to indicate that it owes its existence to the persistence of at least part of the vestigeal tail found in the human embryo. In some of these it seems that the coccyx extends down into the tail, though there is no good evidence that there is ever an increase over the normal number of coccygeal vertebræ in these instances. Under this latter head would come the majority of the adherent (*angewachsene*) tails described by Bartels,[9] and also some

[1] M. Bartels: Die geschwänzten Menschen. Archiv f. Anthropol., Bd. xv, 1884.

[2] These were the rulers of the Jaitwa or Camari, one of the Rajpoot tribes. "They trace their descent from the monkey-god Hanuman, and confirm it by alleging the elongation of the spine of their princes, who bear the epithet 'Pooncheria, or the long-tailed Ranas of Saurashtra.'"—James Tod: Annals and Antiquities of Rajast'han, or the Central and Western Rajpoot States of India, vol. i, London 1829.

[3] Bartels cites an instance of this in the stories regarding a certain community of tailed men in Turkestan. These were held in the utmost contempt by the other people, and were therefore condemned to constant inbreeding. They were referred to as "Kuju rukly Tatar," which in German is rendered "*Stinkendes Ungeziefer mit Schwänzen.*" The tail was supposed to be a special curse in that it hindered the possessor from sitting properly on his horse.

[4] Oskar Schaeffer: Beitrag zur Aetiologie der Schwanzbildungen beim Menschen. Archiv f. Anthropol., Bd. xx, 1892.

[5] I. S. Pyatnitski: On the Question of the Formation of a Tail in Man, and of Human Tails in General, according to Data from Literature and Personal Researches. Dissertation. St. Petersburg, 1893 (Russian).

[6] J. H. F. Kohlbrugge: Schwanzbildung und Steissdrüse des Menschen und das Gesetz der Rückschlagsvererburg. Natuurkundig Tijdschrift voor Nederlandsch-Indië, Deel lvii, 1898.

[7] Dickinson: A Child with a Tail. Brooklyn Medical Journal, vol. viii, 1894.

Halsted Myers: A Caudal Appendage. Proceedings of the New York Pathological Society, (1893) 1894.

Julian Berry: Baby with a Tail. Memphis Medical Journal, vol. xiv, 1894.

A. Ecker: Der Steisshaarwirbel (vertex coccygeus), die Steissbeinglatze (glabella coccygea) und das Steissbeingrübchen (foveola coccygea), wahrscheinliche Ueberbleibsel embryonaler Formen, in der Steissbeingegend beim ungeborenen, neugeborenen und erwachsenen Menschen. Archiv f. Anthropol., Bd. xii, 1880. Ecker describes a case reported to him in a letter from Dr. Neumayer, of Cincinnati.

Miller: Medical and Surgical Reporter, 1881. (Not accessible.)

[8] Archiv f. Anthropol. Bd. xx, p. 219.

[9] M. Bartels: Ueber Menschenschwänze. Archiv f. Anthropol., Bd. xiii, 1881. In this paper Bartels classifies persistent tails, dividing them into two main types, adherent and freely suspended (*freie*); of the latter

cases in which the tail projects free from the trunk as, for instance, cases described by Braun,[10] Ornstein,[11] and by Dickinson. The majority of the embryonic tails contain, however, no prolongation of the vertebral column but are classed as what Virchow[12] calls soft tails (*weiche Schwänze*).

Description of Case.

About a year ago Dr. Watson exhibited before the Johns Hopkins Hospital Medical Society a baby with a tail, which is an example of the last-named class.[13] The tail was removed later, and through the kindness of Dr. Watson, who gave me the specimen as well as his notes of the case, I am enabled to make a fairly complete report on it, including a description of its histological structure.

The child, which was the third in the family, was a healthy, well-developed male. In its family history there is nothing which throws any light upon the case. Aside from the tail the baby presented only one other slight deformity, and that was in the four outer toes of the right foot. These toes were shorter than the normal ones of the left foot, their tips were turned up and the nails were small and thick. The phalanges of these toes were short and there were but two in each toe. The great toe of this foot was normally developed.

The tail appendage was attached in the mid-line about one centimeter below the tip of the coccyx. Examination of the sacro-coccygeal region showed a well marked *foveola coccygea* (Ecker) (Figs. 1 and 2), but owing to the extreme fineness of the hairs of this region, which to the unaided eye were quite invisible, it was impossible to distinguish any particular coccygeal bald spot or *glabella coccygea* (Ecker). Beginning a little to the right and below the *foveola* is a sharply defined groove, which runs obliquely downward and to the left between the buttocks and passes to the left of the root of the tail.

The appendage itself was of firm consistency, though containing no bone. It was covered with normal skin, containing fine hairs, and was apparently well vascularized. Three distinct portions or segments could be made out. The basal piece was short and on the dorsal side scarcely marked off from the next following, except when the tail was in a state of contraction (Fig. 2). On the ventral side a transverse furrow separated it from the next portion. The middle segment had a length of 25 mm., was curved a little to the right and tapered somewhat towards its distal end, where the much more slender end-segment was attached. These two portions were separated by a constriction more marked on the left side. The terminal segment curved to the right and ventrally and ended in a rounded blunt extremity. On the whole, the tail gave an impression not unlike that of a pig's tail, a similarity which has been noted in a number of cases previously reported.

The hairs upon the tail, which were considerable in number, were plainly visible to the unaided eye. They pointed towards the tip, as could readily be confirmed by examination of longitudinal sections (Fig. 4). The convergence of the hairs towards the tip of the tail corresponds with the arrangement of the hairs in the coccygeal whorl (*vertex coccygeus* of Ecker), found in normal, *i. e.* tailless individuals, and supposed to be a vestige of the embryonic tail.

Two weeks after the birth of the child the tail was 4.4 cm. long; at the age of two months it had grown to 5 cm.; and at six months, when it was removed, it had attained the length of 7.0 cm., showing altogether a fairly rapid rate of growth.

The most remarkable characteristic of the tail was its movability. When at rest it would lie extended in the mid-line (Fig. 1), or bent over to one side upon the buttocks. The mother of the child said that she had seen the tail bent through an angle of 180°, its tip pointing towards the head. It must, however, have been brought into this position passively, for, as will be seen later, there was nothing in the arrangement of its muscles which could account for this. When the child was irritated, and cried or coughed, the tail would contract markedly. Between the basal and middle segments but little movement was possible; the contraction of the muscles merely brought out the constriction between the two portions more plainly. Between the middle and distal segments the movement was considerable. The latter could be drawn in sharply, telescoping the middle segment, and at the same time flexion to the left side took place. During this action the middle segment became much shorter and thicker.

When the child was about six months old the tail was removed by Dr. Watson.[14] The amputated appendage was put immediately into Zenker's fluid to harden. After it had been washed and kept in strong alcohol for some time it measured 5.3 cm. in length. It was then cut into four pieces with a sharp razor, and the pieces were imbedded in celloidin. Cross sections were cut at three different levels, near the base, proximal to the second joint, and near to the tip, as is indicated in Fig. 4. After a few transverse sections were cut off, the pieces were stuck together and reimbedded in celloidin for the purpose of cutting longitudinal sections of the whole.

From the study of sections it is seen that the skin covering the whole of the tail except a limited area on the ventral sur-

a number of subdivisions are made, between which, however, the distinction does not seem to me to be sharp.

[10] M. Braun: Ueber rudimentäre Schwanzbildung bei einem erwachsenen Menschen. Archiv. f. Anthropol., Bd. xiii, 1881.

[11] Ornstein: Schwanzbildung beim Menschen. Archiv f. Anthropol., Bd. xiii, 1881.

[12] R. Virchow: Schwanzbildung beim Menschen. Deutsche med. Wochenschr., 10. Jahrg., 1884.

[13] W. T. Watson: Exhibition of a Three-months' Infant with a Caudal Appendage. Proc. J. H. H. Med. Soc. Johns Hopkins Hospital Bulletin, vol. xi, 1900.

[14] It seemed advisable to remove the tail, not only in order to accede to the wishes of the child's parents, who regarded its presence with chagrin, but also on more practical grounds. It looked as if the tail might become the seat of a troublesome intertrigo. Besides, its rate of growth was considerable, and it did not seem unlikely that the appendage might have later attained undue proportions, causing, as has been reported in several instances, considerable inconvenience in sitting. (See Lissner: Virchow's Archiv, Bd. 99, 1885.

face is of normal structure. The layers of the epidermis are easily distinguishable. The thickness of the skin varies somewhat. Near the base of the tail on the ventral side it is found to be quite 2 mm. thick, while on the dorsal surface of the same portion it is scarcely 1.5 mm. Further out, *i. e.* at the middle cut (Fig. 4, *a*), there is the same difference in thickness between skin of the ventral and dorsal surface (Fig. 5), although the skin is here not quite so thick as at the base. Near the tip the thickness throughout the whole circumference is nearly 1.5 mm. The greater thickness of the skin on the ventral side at the base is due principally to the epidermis, the corium being more nearly uniform throughout. In the thickened area the epidermal ridges extend down deep into the cutis, and the papillæ are very long and slender. The various integumentary organs, sweat glands, sebaceous glands and hairs, are numerous and of normal build. In longitudinal sections (Fig. 4) it may be very plainly seen that the hair follicles are obliquely inserted, the hair pointing towards the tip of the appendage. This is without exception the case in the proximal two-thirds of the tail, although the regular arrangement is somewhat disturbed at the crease where the distal and middle segments join, especially on the left side. The corium contains a very abundant supply of elastic fibres which may be readily demonstrated in sections stained by Weigert's method.

Beneath the skin the main bulk of the tail is made up of areolar tissue containing much fat. Blood-vessels, nerves, and striated muscle fibres are imbedded in this mass. There is no trace of anything like the medullary cord or of notochordal tissue, as Gerlach found in the tail of a fœtus of four months.

The voluntary muscle consists of a few bundles of fibres which take origin from the subcutaneous areolar tissue near the proximal end of the middle segment. They lie on the left side not far from the mid-line (Figs. 4 and 5), and run distally in parallel bundles diverging somewhat towards their insertion in the skin just beyond the joint between the middle and distal segments. The majority of the fibres are attached on the left side; a few, however, pass to the skin of the right side; and others are attached to the dorsal surface, and perhaps a few ventrally. The action of the muscle is thus clearly explained by its anatomical relations. There are no muscle fibres running between the trunk and the tail.

On the right side near the middle of the tail there are a few muscle fibres (Fig. 5, *M'*), but these are isolated in small bundles or as single fibres by a dense stroma of connective tissue. Moreover, nearly all of these fibres are in a state of degeneration. The fibrils are less distinct than usual, and the nuclei may be found scattered throughout the substance of the fibres. The muscle is, in fact, in an advanced stage of simple atrophy.

No one of the blood-vessels stands out prëeminently in size. The largest artery is on the left side, held in place by strong connective-tissue bundles. This may be seen in sections through the middle (Fig. 5, *A*), as well as through the base of the tail. There are several smaller vessels in the vicinity. Two small arteries are seen in the right dorsal quadrant near the centre and one just beneath the corium, to the left of the mid-line. The veins are small and inconspicuous. There is nothing to be seen of a tuft-like branching of the vessels as Virchow[15] describes in one of his cases, nor is there anything resembling erectile tissue.[16] There is, however, an abundant supply of blood-vessels in the corium.

A number of small nerve trunks (Fig. 5, *N*) run longitudinally in the areolar tissue of the appendage. The majority of these accompany blood-vessels.

Similar Cases.—While it is not practicable to enumerate here all of the similar cases which have hitherto been reported, there are some which for one reason or other are of especial interest. The tail of a Moï,[17] ten years of age, which had attained the length of over twenty-five centimeters, is interesting on account of its size. Many of the cases have been described very briefly and only as regards external appearance. There are, however, a number of cases which have either been dissected or examined microscopically. These include Greve's case described by Virchow,[18] and cases reported by Meyers,[19] Vinogradow,[20] Rodenacker[21] and Scheboldayeff,[22] all of which agree with the present case in general structure but differ from it in the absence of muscle. In two other cases, however, described by Pyatnitzki[23] and Gerlach,[24] respectively, striated muscle fibres were found, and it is to be assumed that such tissue was present in Neumayer's case, for the tail in this instance could be excited to reflex contraction by stimulation of the sacral region. The complicated arrangement of the muscles found in some instances is associated with the occurrence of bone, as in the case described by Hennig and Rauber,[25] and especially in Kohlbrugge's case.[26] The tail described by Gerlach in a fœtus of 1.6 cm. also contained a continuation of the notochord, which has as yet never been seen in older subjects.

The Tail in the Human Embryo.

The caudal region in human and other mammalian embryos has already been described by Ecker, His, Keibel, Fol, Braun and others. These accounts, while agreeing in the main, bring out considerable differences of opinion as to details. For this reason I give here a further description of the tail

[15] Virchow's Archiv, Bd. 79, 1880.

[16] Bartels: Archiv f. Anthropol., Bd. xv, p. 116.

[17] Caudal Appendage in Man. (From the French of Étienne Raband, in "La Naturaliste.") Scientific American, vol. 50, 1889.

[18] Virchow's Archiv, Bd. 79, 1880.

[19] Proc. N. Y. Pathol. Soc., 1893.

[20] K. N. Vinogradow: On Human Tails. Vrach, vol. xv, 1894 (Russian).

[21] G. Rodenacker: Ueber den Säugethierschwanz mit besonderer Berücksichtigung der caudalen Anhänge des Menschen. Inaug.-Diss., Freiburg i. Br., 1898.

[22] W. Scheboldayeff: Tailed Men. Zemsk. Vrach, vol. vi, 1893 (Russian).

[23] Inaug.-Diss., St. Petersburg, 1893.

[24] L. Gerlach: Ein Fall von Schwanzbildung bei einem menschlichen Embryo., Morphol. Jahrb., Bd. vi, 1880.

[25] C. Hennig and A. Rauber: Ein neuer Fall von geschwänztem Menschen. Virchow's Archiv, Bd. 105, 1886.

[26] Natuurkund. Tijdschr. v. Ned. Indië, Deel. lvii, 1898.

region in several human embryos. This I am enabled to do through the kindness of Dr. Mall, who placed at my disposal his fine collection of human embryos. Two specimens, fourteen and sixteen millimeters long respectively, were found to be especially adapted for this purpose, for it is at this stage that the tail reaches the highest point in its development. The study of these was greatly facilitated on account of their excellent state of preservation, and by the fact that they were cut into perfect series of sagittal sections.

Embryo 144. Greatest Length 14 mm.: Neck-Breech 12 mm.—The tail of this embryo is marked off ventrally by a fold of epithelium which extends cranially from the anus, forming a shallow pit or crease between the anal prominence and the tail. This fold extends to the level of the cranial end of the thirty-third vertebra (Fig. 6), so that from this point on, *i. e.* distal to the third coccygeal vertebra, the caudal end of the embryo projects free from the trunk.

The vertebral column extends throughout but half the length of the tail, in which, therefore, a vertebral and non-vertebral portion may be distinguished.

The terminal portion of the tail or caudal filament is bent dorsally and inclined to the left side, and becoming rapidly thinner distally, ends in a slight knob-like enlargement, which is scarcely shown in the figure. The most conspicuous structure in the caudal filament is the medullary cord, which runs to the tip and there ends in a vesicular enlargement. The notochord and the terminal branches of the aorta and inferior vena cava also extend out into it though not so far as the medullary cord. The filament is supported by a diffuse mesenchymatous network, more concentrated in the ventral side just beneath the integument, which is perhaps an indication of the remains of the post-anal gut found in younger embryos.

Counting from the atlas down, it is clear that there are in all thirty-six vertebræ present, of which the distal seven belong to the coccygeal or caudal region. In the trunk, down through the sacral region, the vertebral bodies are composed of embryonic cartilage, which does not stain intensely. The intervertebral discs, owing to the greater concentration of the cells composing them, stand out in sections as deeply staining bands. Between the vertebral bodies and the discs there is a zone of cells, which stains more intensely than the cartilage and less so than the discs. In the well advanced vertebræ of the lumbar region the intermediate zone is thin and clearly forms a part of the perichondrium of the vertebral cartilages. Beginning with the first coccygeal vertebra this intermediate or perichondrial layer forms a thick pad, especially on the distal surface of the disc. The vertebral body is here proportionately thin, showing itself merely as a lighter streak between the more deeply staining perichondrium of each end. In fact the bodies of the distal coccygeal vertebræ can hardly be spoken of as cartilaginous. In thickness (cranio-caudal) the vertebral bodies diminish steadily throughout the sacral and coccygeal regions, but there is very little diminution in the dorsoventral diameter until the thirty-fourth vertebra is reached. The last three diminish rapidly towards the tip. In the last two the discs are fully as thick as the vertebral bodies themselves. The distal surface of the vertebra is capped by a well marked disc. There is on each side of the intervertebral discs in the coccygeal region a small mass of deeply staining tissue, which projects ventrally and laterally. They are visible only in sections which pass to the side of the mid-line. They represent undoubtedly rudimentary hypapophyses or hæmal arches found in the caudal vertebræ of lower forms.

The spinal ganglia, not counting the ganglion of the hypoglossus, are thirty-three in number. In connection with the last a distinct ventral ramus arises and passes ventrally to the side of the vertebræ, bending distally; ventral to the vertebræ it joins a trunk from the next higher nerve. Its mode of ending is uncertain.

The number of muscle plates could not be made out clearly.

In the interval between the thirty-first and thirty-second vertebræ the medullary cord (*med.*) becomes suddenly attenuated into a *filum terminale*. There are apparently few or no neuroblasts beyond this point; the walls of the tube are made up of columnar epithelial cells. In the distal portion of the vertebral region and at the base of the caudal filament the cord takes a somewhat sinuous course. The central canal extends to the tip of the tail, where it ends in the slight enlargment mentioned above, the terminal ventricle.

The notochord (*ch.*) forms the axis of the vertebral bodies and discs, and in the proximal portion of the coccygeal region, as in the trunk, is almost straight. In the region of the last two or three vertebræ it is more tortuous. It leaves the vertebral column near the dorsal surface of the last vertebral body and passes thence dorsally to the ventral side of the medullary cord, accompanying this nearly to the tip. In contrast to the vertebral portion, the terminal portion is scarcely differentiated and not well defined in the surrounding mesenchyme.

The continuation of the aorta (*ao.*), *i. e.* the *a. sacralis media*, at first ventral to the vertebræ, passes out into the caudal filament as an *a. caudalis*. From this are given off the segmental arteries, one for each vertebra down to and including the last or thirty-sixth. (The last two are not shown in the figure.) These pass up on each side of the vertebral bodies, but it is doubtful if the more distal ones are as yet fully open. In the same way the vena cava continues into the tail, as the *v. sacralis media* and the *v. caudalis*, which lies ventral and to the right of the artery. At their termination in the caudal filament the artery and the vein meet. The vein is of large calibre to the region of the thirty-second vertebra; here it narrows down very suddenly. There are numerous small blood-vessels throughout the mesenchyme of the tail.

Embryo 43. Greatest Length 16 mm.; Neck-Breech Length 14 mm.—The relations of the tail to the trunk are about the same as in the younger embryo first described, *i. e.* it is free from the thirty-third vertebra on.

The vertebral portion of the tail is longer, but the caudal

filament is shorter and more shrunken. It bends sharply on itself to the dorsal side, almost through an angle of 180°.

Thirty-seven vertebræ are present, with possible indications of a thirty-eighth; eight of these belong beyond doubt to the coccygeal region. The thirty-fourth and thirty-fifth are partly fused in the middle. The hypapophyses of each are distinct.

The spinal ganglia number thirty-two. The relations of the notochord, medullary cord and blood-vessels are the same as in the embryo first described. There is a slight irregularity in the notochord in the form of a process which extends ventrally into the substance of the thirty-sixth vertebra.

General Considerations.

Ecker[27] and His[28] were the first to give detailed descriptions of the caudal region of the human embryo. Their conclusions regarding its definition and ultimate development may be taken as the starting point in the discussion of the subject. The agreement reached by Ecker and His may be rendered in part as follows:[29] (1) The term "tail" may be applied only to that portion of the embryo which projects free beyond the cloaca. (2) The tail consists of a portion containing vertebræ and a portion without vertebræ (caudal filament). The latter contains only notochord and medullary cord. (3) Only the non-vertebral portion atrophies. The vertebral portion remains for some time as the coccygeal prominence (*Steisshöckvr*), which, however, gradually disappears in consequence of the increase in the curvature of the sacrum and coccyx, and of the progressive development of the pelvic girdle and its musculature.

Two matters which have a bearing upon the morphological significance of the persisting cœudal appendages in man are brought up in the above for consideration. The one concerns the structure of the tail in the human embryo in comparison with the tail in lower forms; the other is the nature and amount of regressive change which takes place in the human tail during development.

Regarding the first, Keibel[30] discovered an additional fact of importance in the presence of a post-anal gut in the human embryo. Braun's[31] observations on the caudal filament of mammalian and bird embryos are of importance in showing that the caudal filament is of general occurrence and not a peculiarity of the human tail. Again, the occurrence of spinal nerves and ganglia in a number of the coccygeal segments, as shown by Fol,[32] Phisalix[33] and Keibel, the continuation of the aorta and vena cava into the caudal filament, together with the presence of segmental arteries and the hypapophyses or rudimentary hæmal arches in all of the coccygeal segments as described in the present paper, show that the caudal region of the human embryo resembles that of other mammalian embryos in all respects except in size and in the number of its segments.

Concerning the regressive development of the tail considerable difference of opinion has been expressed. Rosenberg, who holds that, strictly speaking, the caudal rudiment in man is not the homologue of the tail of other animals, but is the result of a precocious growth of the medullary cord,[34] considers that the appendage disappears in consequence of the increase in volume of that end of the embryonic body and not through absorption. His,[35] in supporting Rosenberg, makes the statement that no reduction in the number of segments takes place during the development of the human embryo, but that the regressive changes are confined to the caudal filament: this view is confirmed in the agreement with Ecker. On the other hand, Fol and Phisalix find thirty-eight segments in embryos of 8-10 mm., with indications that several of these disappear through fusion in the course of development. Allowing for the possibility that these observers have counted in an occipital segment, there would be in embryos of this size at least thirty-seven trunk segments, which would correspond to thirty-six vertebræ. Keibel finds in an embryo of 8 mm. thirty-five trunk segments, together with a mass of unsegmented mesoderm, equaling two segments in length. Reckoning this as two instead of one segment, as Keibel does, we have again thirty-seven segments, corresponding to thirty-six vertebræ.

The following is an attempt to tabulate the number of segments found in embryos varying in length from 7.5 to 21.5 mm. With the exception of the last column the data are as recorded by the observers themselves. In the last column the number of vertebræ is given which would correspond to the total number of segments after certain changes have been made, such as deduction of occipital segments or addition of unsegmented mesoderm, which seemed justified by the descriptions of the authors.

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[27] A. Ecker: Archiv f. Anthropol., Bd. xii, 1880.

A. Ecker: Besitzt der menschliche Embryo einen Schwanz? Archiv f. Anat. u. Physiol. anat. Abtheil., 1880.

[28] W. His: Anatomie menschlicher Embryonen, I, Leipzig, 1880.

W. His: Ueber den Schwanztheil des menschlichen Embryo. Archiv f. Anat. u. Physiol. anat. Abtheil., 1880.

[29] A. Ecker: Replik und compromissitze nebst Schlusserkärung von W. His. Archiv f. Anat. u. Physiol. anat. Abtheil., 1880.

[30] Fr. Keibel: Ueber den Schwanz des menschlichen Embryo. Archiv f. Anat. u. Physiol. anat. Abtheil., 1891.

[31] M. Braun: Entwicklungsvorgänge am Schwanzende bei einigen Säugethieren mit Berücksichtigung der Verhältnisse beim Menschen. Archiv f. Anat. u. Phys. anat. Abtheil., 1882.

[32] H. Fol: Sur la queue de l'embryon humain. Comptes Rendus, T. 100, Paris, 1885.

[33] C. Phisalix: Étude d'un embryon humain de 10 millimètres. Archives de Zool. Exp. et Gén. IIme S., T. vi, 1888.

[34] E. Rosenberg: Ueber die Entwickelung der Wirbelsäule und das centrale carpi des Menschen. Morphol. Jahrb., Bd. i, 1876. "... dass die Gestaltung des hinteren Leibesendes ebenfalls von dem Medullarohr derart beeinflusst wird, dass letzteres, indem es in seinem Längenwachsthum dem der anderen, un der Zusammensetzung des hinteren Leibesendes Theilhabenden Bestandtheile vorauseilt, an demselben einen Vorsprung erzeugt. . . ." p. 128.

[35] "Es werden demnach beim menschlichen Embryo keine überzähligen zur Rückbildung bestimmten Segmente angelegt." Anatomie menschlicher Embryonen, i, p.92.

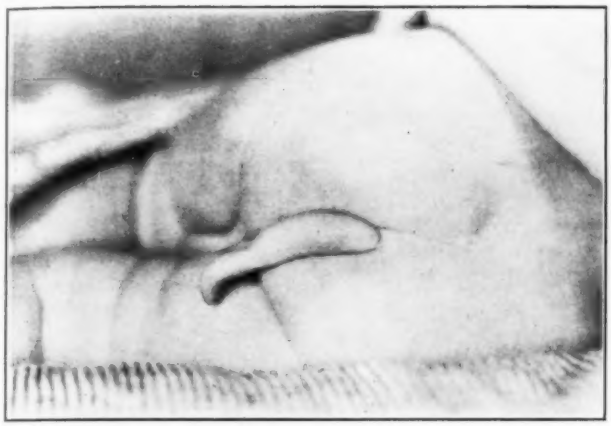

FIG. 1.—Photograph showing tail in extended condition.

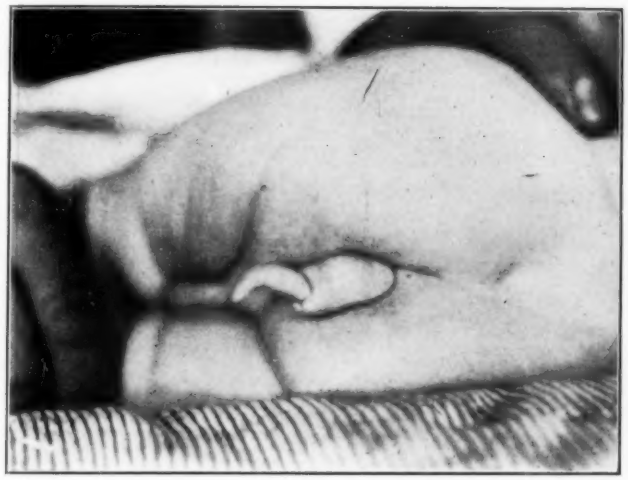

FIG. 2.—Photograph showing tail in state of contraction.

FIG. 3.—Photograph showing the ventral surface of tail.

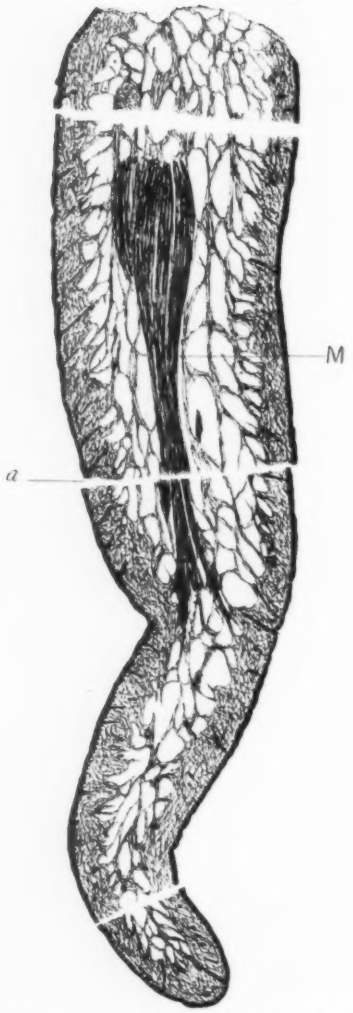

FIG. 4.—Frontal sections of tail, showing the arrangement of the muscle fibres (*M*). a, Place from which the cross-section represented in Fig. 5 was taken. ×3.

FIG. 5.—Cross-section through the middle of the tail (Fig. 4, a). M, muscle; *M'*, degenerating muscle; *A*, artery; *N*, nerve; *L* is placed on the left and *R* on the right of the appendage. ×9.

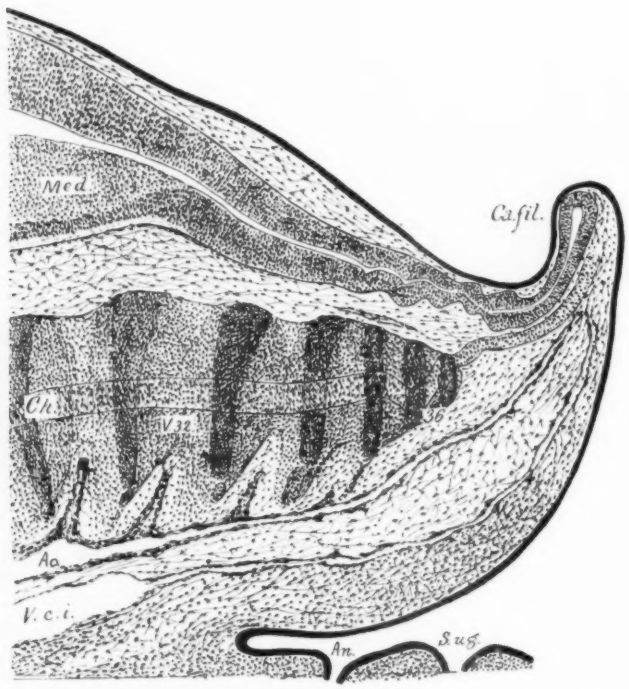

FIG. 6.—Caudal region of embryo of 14 mm. (No. 144 of Dr. Mall's collection), combined from several sagittal sections. *An.*, anus; *Ao.*, caudal aorta (*A. sacralis media*); *Ca. fil.*, caudal filament; *Ch.*, notochord; *Med.*, medullary cord; *S. ug., sinus urogenitalis*; *V.* 32, third coccygeal vertebra; 36, seventh coccygeal vertebra; *V. c. i.*, caudal portion of *vena cava inferior* (*V. sacralis media*). ×91.

Harrison del.

Observer.	Length of embryo in mm.	Segments in mesoderm.	Spinal ganglia.	Vertebræ.	Corresponding number of vertebræ after allowing for corrections.
His	7.5	35	—	34	34
Keibel.....	8.0*	35 + unsegmented mesoderm.	—	—	36†
Fol.....	8.0–9.0	38	—	36	36
Phisalix	10.0	38	36	..	36
Keibel.....	11.5*	35 + unsegmented mesoderm.	34	35	36†
Fol	12.0	..	—	36	36
Harrison ...	14.0	..	33	36	36
Harrison ...	16	..	32	37	37
His	16.0	..	..	34	34
Rosenberg..	16.5	..	..	33	33
Fol	19.0	..	..	34	34
Rosenberg..	19.0	..	..	35	35
His	21.5	..	..	34	34

* Neck-breech measurement.
† Counting the terminal mesoderm as equivalent to two segments.

From this it may be seen that the number of vertebræ or their equivalent is fairly if not quite constant in embryos between eight and sixteen millimeters in length. We have, then, seven vertebræ in the embryonic tail at its highest period of development. The stages studied by His and by Rosenberg were either too young or too far advanced to show the maximum number of vertebræ. That the reduction takes place by fusion, as is maintained by Fol, is confirmed by the study of the embryos described above. In the older embryo (16 mm.), in which an exceptionally large number of segments was present, partial fusion between several of the adjacent vertebræ had taken place. In still older embryos, as seen in the table, the number of segments is inconstant; most probably this is due to the varying extent to which fusion has taken place, though it is possible that it may be due in part to a difference in the original number. As Steinbach[36] shows, the usual number of segments is thirty-four, *i. e.* five coccygeal, although the number may be less or, in rare instances, even increased by one.

The spinal ganglia of the caudal region, as Keibel has shown, also suffer reduction. There are never quite so many ganglia developed as vertebræ, and the last ones are always more or less rudimentary; but there are always more formed than persist in the adult. For instance, in an embryo of 10 mm. Phisalix described thirty-six ganglia; in an embryo of 11.5 mm. Keibel found thirty-four; in the embryo of 14 mm. described above there were thirty-three, and in the embryo of 16 mm. thirty-two, while in the adult there are but thirty-one. The segmental arteries of the distal caudal segments also become obliterated as development proceeds.

We conclude, then, with Keibel that, while as far as outward form is concerned the embryonic tail disappears largely as a result of the growth of the extremities and the gluteal region, a certain amount of regressive change takes place in the caudal appendage itself. This is manifest not only in the absorption of the caudal filament, as supposed by Ecker and His, but also in the reduction of all essential structures of the vertebral portion of the tail, *i. e.* the vertebræ, muscle segments, spinal ganglia and blood-vessels. It is interesting to note that in this tendency to reduction the resemblance between human and other mammalian tails also holds. The caudal filament, as Braun has shown, is present in other embryos and atrophies as development proceeds. The tendency to fusion of the distal vertebræ has been observed in the embryos of various long-tailed animals. And in short-tailed varieties, as Bonnet has shown, this tendency is merely accentuated.[37]

The view that a great many of the anomalous caudal appendages found in man are, as stated in the beginning, due to the persistence of the embryonic tail, is warranted by the facts gathered both from the study of the former as well as of the latter. Many of the differences in form are explained by the hypothesis of Bartels that the embryonic tail may be arrested in any stage of its development. The soft or boneless tails are clearly not due to the multiplication of vertebræ or even to the persistence of all which are developed in the embryo, but, as His[38] first suggested, are to be regarded as persisting caudal filaments. The usual position of these appendages as well as their structure support this conclusion. The fact that they are not always attached exactly over the tip of the coccyx cannot be regarded as conflicting with this view, for, as has long been recognized, the curvature in the vertebral column, especially in the sacral and coccygeal regions, changes markedly during development, and the caudal filament not being firmly united to the tip of the coccyx might easily be shifted slightly in relation to the latter.

In the action of amniotic adhesions Schaeffer[39] has suggested a cause which may undoubtedly bring about the persistence of the caudal filament, for it is a fact that in many, perhaps in a majority of the cases there are other evidences of such adhesions having been present, and, as Schaeffer points out, the caudal region, like other projecting portions of the embryo, is especially liable to stick to the amnion. The adhesions are to be regarded, however, merely as a factor which may induce the persistence of an otherwise transitory structure and it does not follow that such persistence is always the result of adhesions. On the contrary, we find in certain animals that the caudal filament normally persists. According to Braun, this is probably the origin of the tail-stump, composed of areolar tissue, found in Inuus pithecus, and similar apendages are also found sometimes in the Chimpansee, as Rosenberg has described.

[36] E. Steinbach: Die zahl der Caudalwirbel beim Menschen. Inaug. Diss., Berlin, 1889.

[37] R. Bonnet: Die stummelschwänzigen Hunde im Hinblick auf die Vererbung erworbener Eigenschaften. Zeigler's Beiträge z. path. Anat. u. allg. Pathol., Bd. iv, 1889.

[38] Anatomie menschlicher Embryonen, i, p. 95.

[39] Archiv f. Anthropol., Bd. xx, 1892, p. 219.

DEVELOPMENT OF THE PIG'S INTESTINE.

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By the work of Henke[1] and of Weinberg[2] it was first shown that the various parts of the human intestine hold a definite relative position in the body. But it was not until 1897, when the researches of Mall[3] were published, that this subject was put on a satisfactory basis. Professor Mall described in detail the development of the human intestine, the protrusion of loops into the cœlom of the umbilical cord and their return to the general body-cavity. He traced the various loops through different stages in their development and showed that in the human adult these loops are massed together into definite groups, which maintain a constant position in the abdominal cavity.

Merkel,[4] in his handbook, has considered all the literature on the subject and has given a description of his own work, the results of which are in accord with those of Mall.

Dexter[5] has lately described the development of the intestine of the cat. He finds no definite arrangement of the intestinal loops to be present in this animal.

The following notes were made in the study of a considerable number of pig's embryos:

Methods and Material.

In this study there was used a series of pig's embryos varying in length from 12 mm. to 12 cm. An attempt was made to obtain embryos with each stage, showing only the least possible advance on the one preceding it. In some stages several embryos from the same uterus were examined in order to determine the constancy of the loops of intestine in individuals of the same age. Types chosen from the various large groups of lower animals were also studied.

The only method used was one of direct dissection. The embryos were hardened in formalin or alcohol, which rendered the intestines firm and not easily displaced. The abdominal cavity was opened and the liver carefully lifted away and dissected out under water. The Wolffian body and kidney were similarly removed. The umbilical cord was then laid open to expose that part of the cœlom which it contained. In this way the intestines could be well isolated without disturbing them in the least. Starting, then, with the stomach the various loops were followed and modeled with copper wire. This could be bent so as to accurately represent the direction of each loop, and the general position of the loops of wire could be constantly compared with that of the intestinal loops, so that very little error could arise. On reaching the anus the whole intestine was gone over again starting with the rectum and ending in the stomach. In this way any error could be well controlled. The whole model was then compared again with the embryo to see that the surface coils corresponded. To aid in drawing and studying these models the various groups of coils were painted in different colors. The same method was employed in the study of the lower animals. In the simpler types, however, the wire models were unnecessary. In the earliest embryos also the arrangement could be made out perfectly well without modeling.

Description of Dissections.

Until the embryonic pig has reached a length of about 10 mm. there is in every case some part of the intestine in the umbilical cord. The portion nearest the stomach develops entirely outside the cord; while what corresponds with the lower end of the ileum, together with the cœcum and a short stretch of the large intestine, remain in the cord until the stage mentioned above. The part in the neighborhood of the cœcum is the last to leave the cord. All the loops which develop within the cord belong to the part of the intestine corresponding in position with the lower end of the ileum. This develops more slowly than the intra-abdominal portion of the gut.

In the following descriptions the terms "right" and "left" refer to the pig's body and not to the figures themselves. "Anterior" and "posterior" refer to the head and tail ends respectively; while the terms "dorsal" and "ventral" are used in their ordinary sense. The figures are all drawn from the right side of the embryo's body unless otherwise indicated.

Figure 1 represents an early stage in the development of the pig's embryo, in which the intestine consists of a single loop extending out into the umbilical cord. The embryo itself is 12 mm. long and the loop in the cord is slightly less than 3 mm. in length. This loop is somewhat curved with the concave surface towards the head. As represented in Fig. 1 the intestine is sharply bent on itself in the cord, and on its return to the main body-cavity it turns at an acute angle to form the rectum. I can discover no trace of a cœcum at this stage other than a slight enlargement of the tube just after it bends in the cord. The arm of the loop which extends from the stomach into the cord is destined to give rise to the small intestine; while the arm returning from the cord to the rectum is, roughly speaking, the forerunner of the large intestine. Several embryos of this size were examined, and the condition described above found to be constant.

In Fig. 2 there is shown the dissection of a pig's embryo, 18 mm. in length. The loop of intestine extending into the cord is much like that represented in Fig. 1. A distinct cœcum, however, can be made out in the rectal arm of the

[1] Henke; Arch. f. Anat. und Phys. Anat. Abth., 1891, S. 89.

[2] Weinberg; Internat. Monatsch. f. Anat. und Phys., xiii Bd., 1896.

[3] Mall, F. P.; Arch. f. Anat. und Entwickelung. Anat. Abth. Supplementband, S. 403, 1897; and Anatom. Anz. Bd. 16, S. 492, 1899.

[4] Merkel; Handbuch der Topographischen Anatomie, ii Bd., 1899.

[5] Dexter, F.; Arch. f. Anat. und Phys., Anat. Abth., 1899.

loop, a short distance from where the intestine bends on itself. This cœcum is a short blind sac having an appearance very much like that shown in the figure. It will be noticed that a considerable part of the body-cavity is, in this stage, in the umbilical cord. Fully half the length of the intestine is contained in this extra-abdominal cœlom. Just inside the main body-cavity a loop is beginning to be formed in the small intestine. Its bends are marked 1, 2 and 3. From the stomach it extends dorsally and to the right. Turning sharply it runs ventrally and to the left, and before entering the cord it proceeds again posteriorly. On comparing Figs. 1 and 2, there is seen a greater change in this part of the intestine near the stomach than in the part contained in the cord. The large intestine beginning at the cœcum turns and passes into the rectum as before. Several embryos of this size showed an identical structure.

Fig. 3 represents a pig 21 mm. long. The portion of the intestine in the cord is still unchanged, while that in the body-cavity proper shows a further development of the same loops seen in Fig. 2. In comparing the numbers on the two figures there is no difficulty in recognizing the corresponding parts. The cœcum holds the same relative position as in Fig. 2. After entering the cord at the loop 3 in Fig. 3 the intestine bends in a curve with the concave side towards the head. It then turns abruptly backward and to the left, and returns to the main body-cavity by almost the same path. This is represented plainly in Fig 3, and it will be noticed in the succeeding stages that this particular arrangement of the intestine as it turns is quite characteristic.

Fig. 4 shows a somewhat more advanced stage in the development. It is drawn from the dissection of a pig 23 mm. long. The general position of the intestine is very similar to that just described. The loops, however, have increased in number; and instead of one entire loop, as represented in Fig. 3, there are three, indicated by the letters *a*, *b* and *c* in Fig. 4, *B*. In Fig. 3 the stomach narrows into the small intestine, which bends rather abruptly, and forms one complete loop overlying the large intestine. In Fig. 4 the same thing occurs, but following this first loop are two others. As shown in the figures there is a tendency for the loops to grow around the large intestine from the right side. The large intestine is on the left side of the small intestine and somewhat anterior. The part of the small intestine contained in the cord is less changed, and its growth is apparently somewhat slower. There is, however, to be seen the beginning of a new coil marked *x* in Fig. 4, *B*. This is an incompletely-formed loop and shows well the way in which the loops develop. It is simply a bending, as though the intestine had grown too long for the space it was obliged to occupy. Before reaching the cœcum the small intestine turns on itself in the characteristic way described in Fig. 3. The large intestine is unchanged.

In Fig. 5 the same loops are seen in the first part of the small intestine, and those marked *a*, *b* and *c* correspond fairly well. In the cord, however, there are here too loops instead of the one shown in Fig. 4. These occur in the small intestine opposite the cœcum and have relatively the same position as the bending of the tube marked *x* in Fig. 4. They are lettered *x* and *y* in Fig. 5. The remainder of the intestine is the same as in Fig. 4. The length of this pig was 25 mm.

Fig. 6 represents the intestine of a pig of approximately the same length as that shown in Fig. 5. The small intestine in the main body-cavity, however, is slightly more advanced in development. The various loops can be readily recognized and much more easily so on the wire model than on the drawing. A very slight change in the general position of a loop causes a most decided difference in a flat drawing. The main difference, for example, between Figs. 5 and 6, is the dislocation of the loop *z* towards the stomach. By comparing the lettering in the two figures this can be easily understood. The part of the intestine in the cord is practically the same in the two figures.

Thus far the large intestine is a simple tube bending sharply near the stomach to form the rectum. It will be noticed that the small intestine has grown much more rapidly than the large intestine; and also that the part of the small intestine near the stomach has increased in length more rapidly than the part in the cord. Several pigs, the same size as these last two described, were examined, and their intestines found to be similar in every way. Embryos taken from the same uterus did not seem to resemble one another in this respect more closely than pigs of the same length from different uteri.

Fig. 7 represents a dissection of a pig's embryo 28 mm. in length, and Fig. 8 is a drawing of the wire model made from this intestine. The stomach, it will be seen, occupies the same position and narrows into the small intestine in the same way as before The small intestine here forms a distinct mass of loops in the main body-cavity, and then extends out into the cord in a manner identical with that shown in earlier embryos. The loops form a cone-shaped mass with the base of the cone towards the stomach and its apex in the umbilical cord. This is due to the more rapid growth of that part of the small intestine near the stomach. This arrangement will be noticed in all the older embryos as well until after all the coils have returned to the main body-cavity. It is a little unsatisfactory to attempt to follow the individual coils of the intestine, and to trace them from one embryo to another after their arrangement has reached a complexity as great as that shown in Fig. 8 and the figures following. But if the two models represented in Figs 6 and 8 be compared, there will be seen a certain correspondence which can hardly be overlooked. The identity of the two loops in the cord marked *x* and *y* is recognized at first glance. In this part of the intestine there seems to have been very little if any change. The coils near the stomach, however, are distinctly more complicated in Fig. 8 than in Fig. 6. The slight bend in Fig. 6 marked *e* is accentuated into the loop marked *e* in Fig. 8. The letters *a* and *z* mark corresponding parts in the two figures; and the loop *b* can be readily derived in Fig. 8 from the *b* in Fig. 6. Following this, however, there are in Fig. 8 three distinct loops, *c*, *d* and

f, without counting *x* and *y*; while in Fig. 6 there is only one without considering *x* and *y*. At *d* in Fig. 6 there is the beginning of a new loop, as yet only a slight bending in the tube, and *c* corresponds with one of the three loops spoken of in Fig. 8. There is then in Fig. 6 only one entirely new loop not indicated in Fig. 6.

The cœcum maintains the same position in Fig. 8 as in Fig. 6. The bend in the large intestine, however, where it passes into the rectum, shows quite a distinct alteration. It no longer forms a simple acute angle with the rectum, but is bent in two directions as shown in Fig. 8. This is the beginning of the formation of a very distinct group of convolutions which is perfectly constant and will be described below.

The general tendency in the formation of new loops in the small intestine is for the tube to become slightly bent on itself and to grow around an axis which is represented by the large intestine. The characteristic shape of the loops is shown in Fig. 8, *d* and *f*. The loops do not meet above (on the surface towards the head of the embryo); for the large intestine is situated between the bends of the loops in such a way that it could be lifted away from the small intestine by drawing it towards the head, but not by drawing it towards the tail of the embryo. The arrangement becomes less regular the nearer it is to the stomach, for the growth in this region is more rapid and the pressure exerted on the coils greater than in other parts.

Fig. 9 represents the dissection and Fig. 10 the model of the intestines of a pig 30 mm. long. The general position of the various parts is much like that in Fig. 8. By following the letters on Figs. 8 and 10 the corresponding loops can be made out. There are yet no groups of coils to be distinguished. The small intestine can be roughly compared with a hollow cone whose axis is represented by the large intestine. The loops *x* and *y* have become more fully developed and grow around the large intestine in the characteristic fashion. The loops in the figures are lettered only on the right side, since they are in a certain sense duplicated on the left side of the large intestine. A loop, however, is a fold which begins and ends somewhere in the same neighborhood; and it might be possible to take the median line as the starting point, and make loops on either side; but it is much simpler to treat as complete loops only those folds which start on one side and return to that side.

The large intestine in Fig. 10 holds a straight course from the cœcum until it reaches the stomach. It then makes a complete bend on itself and enters the rectum as shown in Fig. 10, *g*.

Fig. 11 is the dissection of a pig 32 mm. long, and Fig. 12 is a drawing of the model made from its intestinal canal. A certain general resemblance in outline is seen between Figs. 10 and 12. The intestine is a cone-shaped mass in each with the apex extending a short distance into the cord and the large intestine forming an axis for the cone. The arrangement of the small intestine in relation to the large intestine is the same as that spoken of before. The loops are bent around the axis of the large intestine, especially near the apex of the cone, *i. e.* near the cord. At the stomach end the gut has become so twisted that the individual loops cannot be traced with any satisfaction. Certain landmarks, however, can be recognized. For example, the loops *x*, *y*, *f* and *d* correspond fairly well in the two stages, and it is not difficult to conceive of the transformation of the loop *c* in Fig. 10 to the same loop in Fig. 12. This transformation takes place by a flattening of the loop which will be spoken of later. It gives rise to a figure which is often seen in the intestines of pig's embryos.

Although the loops can no longer be individually followed with ease, there begins at this stage to arise a grouping of the coils. In Fig. 12 four fairly distinct groups can be made out. Starting with the stomach end the intestine forms a mass of loops which are situated mainly on the left side of the body. In no place does a whole coil of this group reach the surface of the intestinal cone on the right side. This will be called group *A*. After bending in five or six loops, as represented in the more lightly shaded part of Fig. 12 near the stomach, the gut reaches the right side and forms a group of more or less flattened coils, which form all the surface coils of the right side up to nearly the beginning of the cord. This group is shaded darkly in Fig. 12 and ends after the loop marked *d*. It includes the coil *c* described above and will be designated group *C*. The intestine leaves this region at the termination of loop *d*, and forms three complete loops of the type described in earlier embryos. These are unshaded in Fig. 12 and include *f*, *x* and *y*. They form the group *D*. These coils are associated more closely than the rest of the intestine with the cœlom of the cord. At the end of this group the small intestine takes a straight path for a short distance and turns on itself in the way seen in all the embryos so far pictured, and enters the large intestine at the cœcum. The large intestine is straight as before until it reaches the region where it turns to form the rectum. Here it is thrown into irregular twists, as shown in Fig. 12, *E*. The convolutions formed in this region will be spoken of as the rectal group or group *E*, and will be followed through the various embryos. At this stage it is directly anterior (towards the head) and lies partly between the groups *A* and *C*.

Fig. 13 represents the model of the intestine of an embryo 40 mm. in length. The general outline of the mass of coils is, as before, cone-shaped. This is accentuated by the increasing complexity of the rectal group, and by the rapidity of growth of the first part of the small intestine. The same groups described above can be recognized at this stage. The group *A* has increased considerably in length in Fig. 13 and can be divided into two groups which are marked *A* and *B* in Fig. 13, *II*. These become more distinct in later stages. From *B* the gut passes over to the right side of the body and forms the group *C* which is situated entirely on the right side, and makes up most of the surface coils there. This is shaded in Fig. 13, *I*. On approaching the cord there are found the three complete loops described in Fig. 12, as making up group *D*. These are almost identical in the two stages, and

extend into the cœlomic cavity of the cord, which has become gradually more shallow. The rectal group is more complex than in the preceding stages and forms a conspicuous mass of coils whose calibre is noticeably smaller than in the rest of the intestine. Its position also has altered. Instead of lying between groups *A* and *C*, it is to the right of *C*, having rotated on an axis corresponding approximately with that of the cord.

Figs. 14 and 15 represent the dissection and model respectively of the intestine of an embryo 48 mm. in length. At this stage all the coils are within the main body-cavity. The large intestine begins on the right side of group *D*, a short distance from its apex. The cœcum corresponds fairly well in position with that in Fig. 13. On leaving the cœcum, however, the large intestine passes obliquely down on the right surface of group *C*, and is coiled to form the rectal group, posterior to groups *A* and *B*. Fig. 14 does not justly represent the regularity of the loops making up group *C*. They form a series lying transversely from right to left, and can be easily separated in a mass from group *D* on the one hand, and groups *A* and *B* on the other.

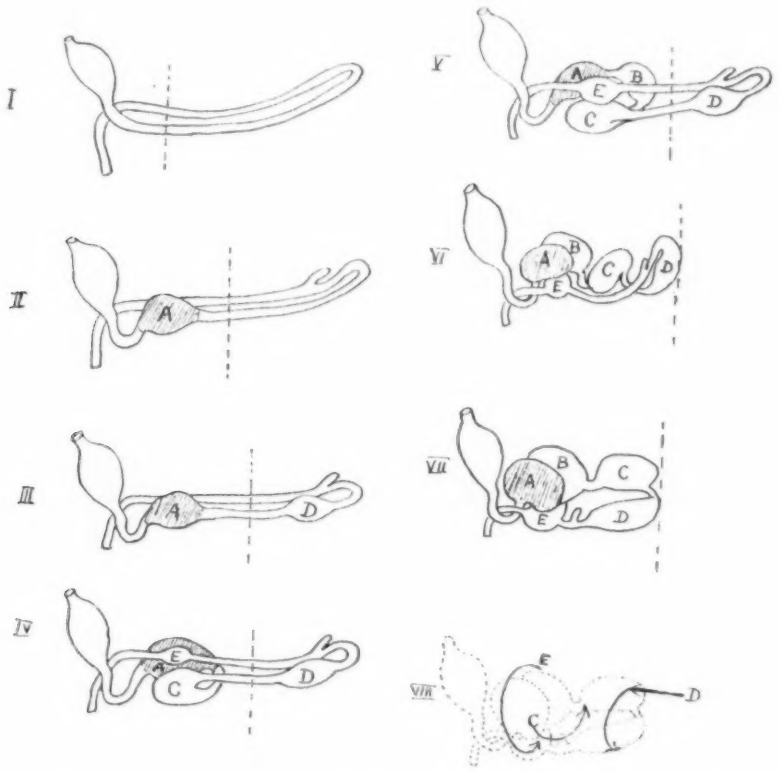

FIG. 18.—A series of diagrams to indicate the formation of groups of coils in the intestine. These represent the intestines of embryos, 12, 21, 25, 32, 40, 48 and 85 mm. in length respectively. The groups are lettered in correspondence with the preceding figures. *VIII* shows the direction in which the groups have rotated, their course being marked by curved arrows.

groups described above can be readily recognized, but a considerable change in their position has taken place. The surface coils near the stomach are derived from group *A* instead of group *C*, as in the stage represented in Fig. 13. Group *A* is on the right side of the body, and group *B* on the left. Group *C* has moved in a ventral direction and somewhat to the left, until it lies transversely between group *D* and groups *A* and *B*. Group *D* enters the main body-cavity and the regularity of its coils is lost. Instead of being complete and regular, as in Fig. 13, the loops are distorted and flattened by their association with the other abdominal viscera. The more or less pointed extremity of this group is still directed towards the cord, as shown in Fig. 14. The

Fig. 16 represents the surface coils of the intestine of a pig's embryo 85 mm. long. Fig. 16, *I* is drawn from the animal's right side; Fig. 16, *II* from its ventral surface; and Fig. 16, *III* from its left side. The various groups of coils are lettered in correspondence with those pictured in Fig. 17, which is drawn from a wire model of this intestine. The surface coils on the right side are formed by groups *A* and *D*. On the ventral surface groups *B* and *C* are present; while the left side is occupied by parts of *B* and *D* and the whole of group *E*. In this stage the same five main groups, that have been described, can be made out. It will be noticed, however, that their relative position is somewhat different. Group *D* has rotated posteriorly, dorsally and to the right, so

that it takes up a position to the right of, and posterior to, group *C*. It thus moves past group *C* and carries the cæcum with it, so that the beginning of the large intestine lies dorsally, and posterior to group *D*. The group *E* is pushed still farther in the same direction until it is finally situated in the left dorsal region of the mass of intestines. This group in the beginning lies on the left anteroventral surface. As it becomes more complex it moves around to the right until it reaches the left dorsal position. It therefore rotates through three-quarters of a circle. The axis of this rotation is a line drawn from the beginning of the duodenum to a point somewhat posterior to the umbilical cord.

Fig. 18 consists of a number of diagrams of the different stages, showing this rotation of the groups. The straight dotted line in each diagram represents the junction of the main body-cavity and the cœlom of the cord. Diagram VI corresponds with Fig. 15, and VII with Fig. 17. The younger stages can be easily recognized. Diagram VIII shows the direction in which the groups rotate. The letters in all the diagrams correspond with those used in the description of the groups; and in VIII these letters, associated with the curved arrows, indicate the direction in which those groups have moved from their original positions.

An appearance which is characteristic of the older embryos is shown in Fig. 16, *I*, *D* and *C*; and in Fig. 16, *II*, *C*. The regular loops, which have been described, become flattened by pressure against the abdominal walls, giving rise to the peculiar coiled appearance represented.

The intestines of several embryos older than those represented in Figs. 16 and 17 were studied. The groups were found to correspond with those already described; and an account of these later embryos would not add any essentials to the above description. It is possible in these to tell with considerable accuracy to what group any one surface loop belongs.

It will be noticed that in the older stages, which have been described, the large intestine grows more rapidly than it does in earlier embryos. In those represented by the first eight figures there is practically no change in the large intestine. After this, however, there gradually appears a considerable mass of coils to form the rectal group. The part of the small intestine which is at first present in the cord grows more rapidly after its return to the general body-cavity. For this reason as well as on account of the pressure exerted by the other viscera, the cone-shaped mass of intestines becomes more or less spherical after it is entirely intra-abdominal. The growth, which in earlier stages was almost solely in the region of group *A*, is in the older embryos more uniform throughout the gut. The younger the embryo, the more noticeable is this rapid growth in the region of group *A*. This fact was observed by Dr. Mall and indicated in his paper by means of tables of measurements. In connection with this it is of interest to note an observation made by Berry,[6] who found that the villi appear first in the upper part of the intestine. Whether or not the number of villi increases more rapidly in this region than lower down, has not been determined.

In reviewing a considerable number of embryos in this way and modeling their intestines by a method in which errors can be easily controlled, one cannot help being struck by the remarkable constancy of the appearances met with. At first glance it is more noticeable in the earlier embryos. This fact is due to the greater simplicity of the loops and to the smaller chance for distortion of the coils by pressure. It will be noticed that there is practically no variation in the portion of the intestine contained within the cord. In that part of the body-cavity there are no other viscera to interfere by pressure with the growth. If it were possible to isolate an organ during its development, its form would undoubtedly be different from what it is when it develops a contact with many other growing organs. The portion of the intestine which develops in the cord is to a certain extent isolated. The rapidly-growing viscera, such as the liver and urinary organs, can in no way interfere with its growth; and it is seen from the above descriptions that it is this part of the intestine in particular, which is entirely constant in its appearance. Here the intestine increases in length by the formation of regular loops which grow up and surround the large intestine, as already stated. At first sight it would appear that this manner of growth might be caused by the confinement of the intestine in the cylindrical cavity of the cord; but the same method of formation of loops takes place in the general body-cavity before any loops whatever appear in the intestine of the cord. Since it thus takes place in two parts of the intestine under different conditions, it is fair to assume that this is the natural tendency in the growth of loops in the intestine of the pig.

Dr. Mall, in the publication already referred to, has discussed the entry of the intestinal loops into the cœlom of the cord, and their return to the general body-cavity. He inclines to the belief that the gut is forced into the cord by the pressure exerted on it by the other rapidly-growing viscera; and that it returns to the main body-cavity on account of a twisting of the loops already contained in the abdomen. The dissections of the pig's embryos, which have been described, throw no new light on this subject. The cœlom of the cord in early pig's embryos is of considerable size and the intestine is at first only a single loop. Hence it is not hard to imagine its being pushed into this easily available space in the cord. Here it remains until the secondary loops are formed, which make up group *D*. This group is more or less cone-shaped and fits into the cavity of the cord which has a similar form. The passing of this group to the main body-cavity does not take place one loop at a time. The group returns apparently by a gradual obliteration of the cone-shaped cavity of the cord from its apex to its base.

It can hardly be said that the coils enter the abdominal cavity from the cord in any regular order. The order of their entry is dependent on their position in the mass of coils which projects into the cord. The apex of this mass is formed by

[6] Berry, J. M.; Anatomischer Anzeiger, xvii Bd., S. 242, 1900.

the lower end of the ileum where it turns on itself to join the large intestine. The apex leaves the cord last, and hence the lower end of the ileum is the last part to enter the abdominal cavity. In the same way the cœcum enters a short distance in front of this part of the ileum, simply because it is so situated in the group of coils.

In connection with the development of the mammalian intestine, I wish to call attention very briefly to the intestines of the various lower vertebrates. In Amphioxus the alimentary canal consists of a simple straight tube with no convolutions whatever (Fig. 19, *A*). In the shark the intestine is straight, but the stomach is bent on itself so as to form a descending, and an ascending part (Fig. 19, *B*). In the perch, as in most Teleosteans, there is one distinct loop in

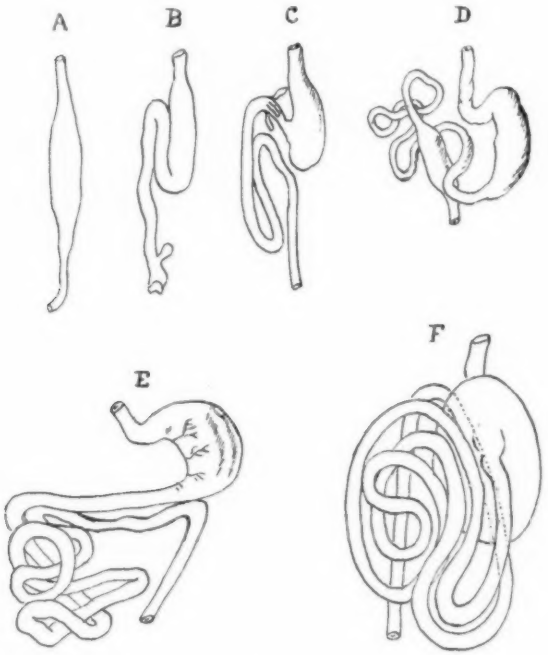

Fig. 19.—Diagrams representing the intestines of *A*, Amphioxus; *B*, Shark; *C*, Perch; *D*, Frog; *E*, Turtle; *F*, Sparrow.

the intestine, as shown in Fig. 19, *C*. There are two methods in these animals by which the digestive surface is increased in extent, namely, by the so-called spiral valve and by the pyloric cœca. The spiral valve consists of a longitudinal fold extending into the cavity of the intestine. It is present in all Elasmobranchs, Dipnoi and Ganoidei, but not usually in the Teleostei. The pyloric cœca may be very numerous and form a large mass of processes just below the stomach. The spiral valve and the pyloric cœca are seldom both highly developed in the same animal.

In the Amphibia the intestine is, as a rule, much more complex than in the fishes. As shown in Fig. 19, *D*, the frog's intestine is considerably coiled. In a number of frogs and toads which were dissected, the intestines were found to be arranged according to a general type which is represented in Fig. 19, *D*. In some cases, however, the coils assumed a much more complicated mass than that shown in the figure. It is interesting to note here that in some stages of the tadpole's life the intestine is a much more complex organ than in the adult frog. The intestine of Necturus shows a coiling which is usually not so great as in the frog.

In the Reptilia the form of the alimentary canal is considerably modified by the shape of the body. In Fig. 19, *E*, is represented the stomach and intestine of a turtle. This is an arrangement which was found to be very constant. In snakes the coils are not so numerous and are somewhat obliterated by the narrowness of the body. In lizards the intestine is coiled more than in either the turtle or the snake. Thus it is seen that in reptiles, and amphibians there is a much more complex arrangement of the coils of intestines than in fishes.

In birds there is a still greater complexity in the form of the intestine. Birds of the same species show very little variation in the arrangement of the coils. In a number of sparrows, robins and blackbirds the arrangement was found to be according to a type represented in Fig. 19, *F*. There was very little divergence from this type in any of the specimens examined. In the chicken, however, there is a far greater coiling. In several chickens examined there was found a noticeable constancy in the arrangement of the loops. A long duodenal fold extends from the gizzard backward and to the left side of the body. Turning on itself it passes to the right side of the body, where the small intestine is thrown into a number of coils which resolve themselves into two main groups. From the rectum two long cœca extend forward.

In the study of these few lower vertebrates two main points are to be observed: (1) the constancy in the arrangement of the loops in nearly related animals; and (2) the gradual increase in complexity of the coils as we pass from the lowest vertebrates to those higher up in the scale. It is interesting to note also a certain relation which seems to exist between the ontogeny of the intestinal canal in mammals, and its phylogeny. Beginning with a straight tube in the early mammalian embryo the intestine is thrown into a gradually increasing number of loops. Beginning in the same way with Amphioxus we may pass from the fishes, which possess but a single loop, to the amphibians, whose intestine is much more complex; and from these to the birds and mammals, where the alimentary canal is a very much coiled organ.

Recapitulation.

The intestine of a pig's embryo at an early stage consists of an uncoiled tube which sends a single loop out into the cœlom of the cord. The first half of the loop is on the right side and gives rise to the small intestine. From the other half is formed the large intestine. The gut increases in length by the formation of regular loops which grow around an axis corresponding with that of the cord and the large intestine. These loops form first in the part which is to become the small intestine. They also develop in that part of the small intestine near the stomach before they appear in

the cord. Up to a certain stage the further growth in complexity is greatest near the stomach. After the small intestine has become considerably coiled, a mass of loops is formed in the large intestine. In embryos between 35 mm. and 40 mm. in length the group of coils which has formed in the cœlom of the cord, enters the general body-cavity by a mechanism which is not clearly understood. In embryos of the same size the coils are constant in arrangement and definite in their position. They can be followed through various stages of the early development. In older embryos, when the individual coils cannot be recognized with ease, they are found to be arranged in distinct groups which have definite situations in the body-cavity. The loops in a certain region of the body-cavity, though they may vary in form, always belong to the same group. These groups arrive at their final situation by a rotation which takes place posteriorly and to the right around an axis, running from the beginning of the duodenum to a point a short distance posterior to the opening of the cord. It is not at all claimed that the surface coils hold always the same position with regard to one another, or that the coils always have the same relation to one another in the group; but it is to be emphasized that the groups always do hold the same relative position in the body.

In lower vertebrates the intestine increases in complexity as we ascend the scale. The intestinal coils are very similar in nearly related animals; and a certain amount of constancy is noticed in their arrangement.

I regret that I have had no opportunity of confirming Dexter's work on the cat's intestine, in which he finds no constancy in the position of the loops. However, from the researches, already referred to, of Henke, Weinberg, Mall and Merkel, as well as from the present study of pig's embryos and the intestines of lower vertebrates, it seems plain that the intestinal canal is an organ which is situated in the body in a definite position, and that its different parts hold a constant relation to one another.

DESCRIPTION OF PLATES XIX-XX.

FIG. 1.—Pig's embryo 12 mm. long, showing a single loop of intestin extending into the umbilical cord.

FIG. 2.—Pig's embryo 18 mm. long, showing a loop of intestine in the cord with a distinct cæcum. The small intestine shows the beginning of coils inside the main body-cavity. The dotted line indicates the original outlines of the body before the removal of the liver.

FIG. 3.—Pig's embryo 21 mm. long, showing a slightly more convoluted small intestine. The numbers 1, 2 and 3 correspond with those on Fig. 3.

FIG. 4.—*A*. Dissection of pig's embryo 23 mm. in length.
B. Wire model of the intestine of this embryo.

FIG. 5.—Wire model of intestine of pig's embryo 25 mm. long. The lettering corresponds with that in Fig. 4, *B*.

FIG. 6.—Wire model of intestine of pig's embryo 25 mm. long.

FIG. 7.—Dissection of pig's embryo 28 mm. long.

FIG. 8.—Wire model of intestine of the embryo represented in Fig. 7.

FIG. 9.—Dissection of a pig's embryo 30 mm. long.

FIG. 10.—Wire model of intestine of embryo represented in Fig. 9.

FIG. 11.—Dissection of a pig's embryo 32 mm. long. *C*, superficial group of coils on right side of body. The small letters correspond with those used above.

FIG. 12.—Wire model made from the intestines of the embryo represented in Fig. 11. *A*, *C*, *D* and *E*, indicate the formation of groups of coils. The group *C* is shaded.

FIG. 13.—Wire model of intestine of an embryo 40 mm. in length. The groups are lettered as in Fig. 12.

FIG. 14.—Dissection of a pig's embryo 48 mm. long. The letters as before indicate the groups of coils.

FIG. 15.—Wire model of intestines of embryo represented in Fig. 14. Groups are indicated by shading.

FIG. 16.—Dissection of a pig's embryo 85 mm. long. *I* shows the intestines from the right side; *II* from the ventral surface; and *III* from the left side. The lettering corresponds with that in the previous figures.

FIG. 17.—Wire model of intestine of embryo represented in Fig. 16.

NOTE:—No attempt has been made to retain the relative size of the embryos in these figures. The actual measurements are given in each case.

BILATERAL RELATIONS OF THE CEREBRAL CORTEX.

BY E. LINDON MELLUS, M. D.

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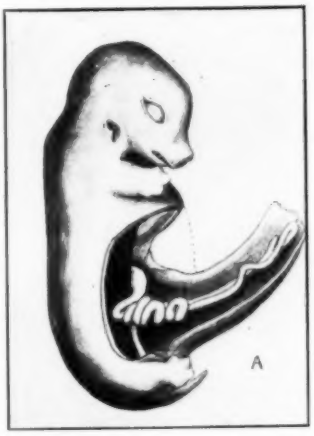
In the study of the central nervous system it becomes more and more apparent that the statement that each cerebral hemisphere controls the opposite half of the body must be still further modified. It has long been recognized that certain movements were more or less bilateral; that is, equally controlled by each hemisphere. This is easily demonstrated by electrical stimulation of the cortex and, to a certain extent, the anatomical relations have been worked out. The bilateral representation of most facial movements would appear at first thought to be quite essential and anatomists held, long before it was demonstrated, that each of the motor nuclei in the pons and medulla was connected with its fellow of the opposite side by decussating fibres. Bilateral movement could thus be accounted for by simultaneous stimulation of the nuclei of both sides, but the results of some of the more recent investigations show that projection fibres run directly from the cortex of each hemisphere to the nuclei of both sides. This provides for simultaneous stimulation, while the fibres passing directly from one nucleus to the other may conserve the symmetrical discharge of energy.

The necessity for bilateral control of the limbs is not so evident, but the fibres of the so-called direct or uncrossed pyramidal tract in man and the finding of bilateral degeneration in the cord after unilateral lesion of the brain seemed to make it probable. For some time it was not possible to trace the course of this homolateral degeneration from the

FIG. 1.



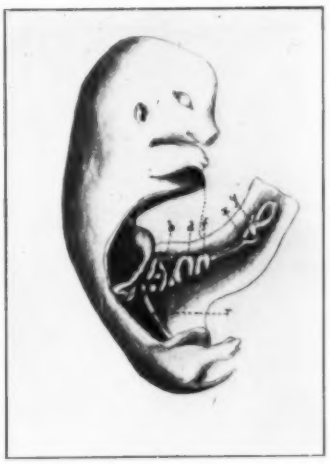


FIG. 7.

FIG. 2.

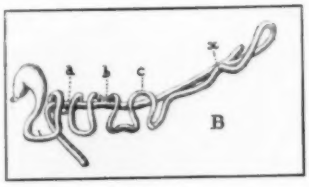


FIG. 4.

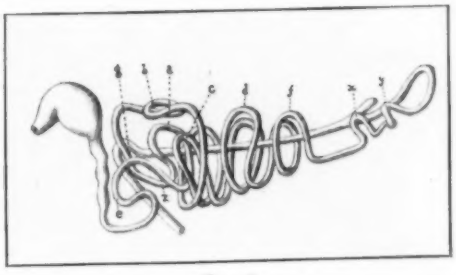


FIG. 8.

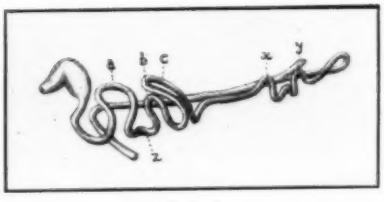


FIG. 5.

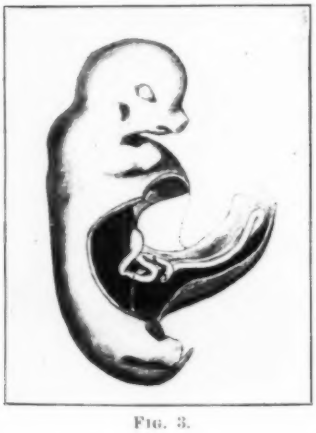


FIG. 3.

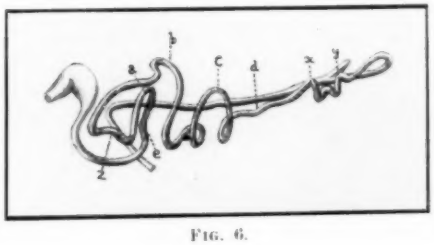


FIG. 6.

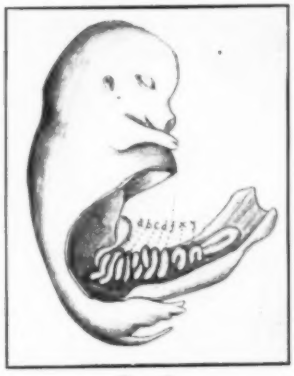


FIG. 9.

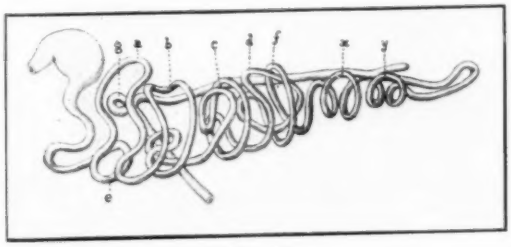


FIG. 10.

FIG. 11.

MacCallum del.

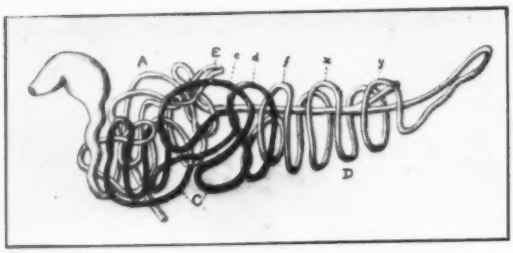


FIG. 12.

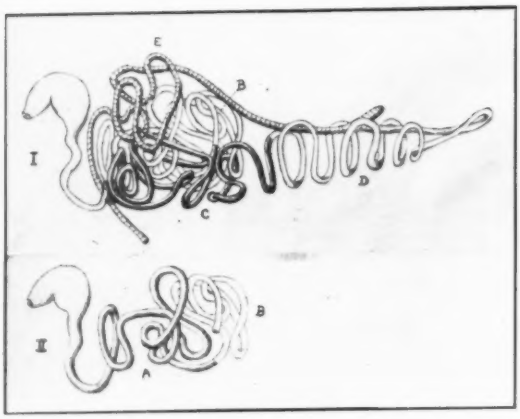


FIG. 13.

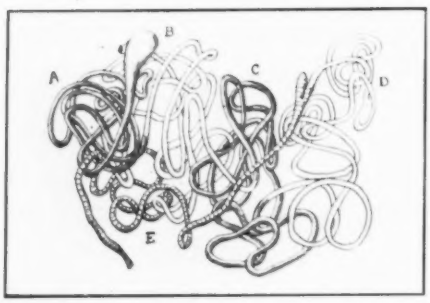


FIG. 15.

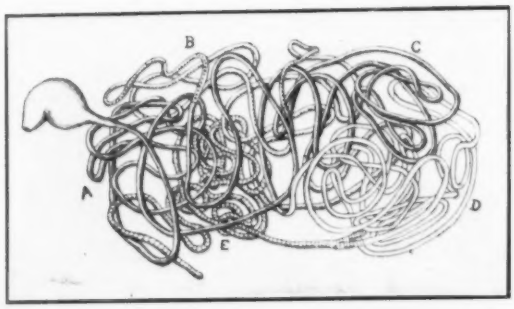


FIG. 17.

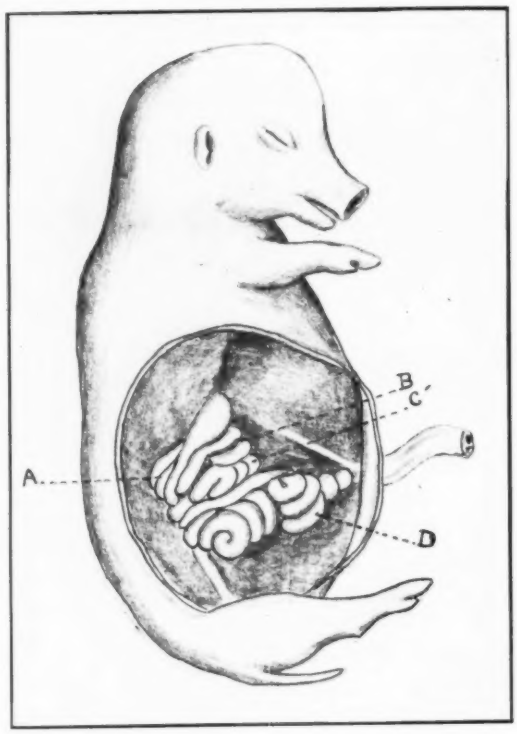


FIG. 14.

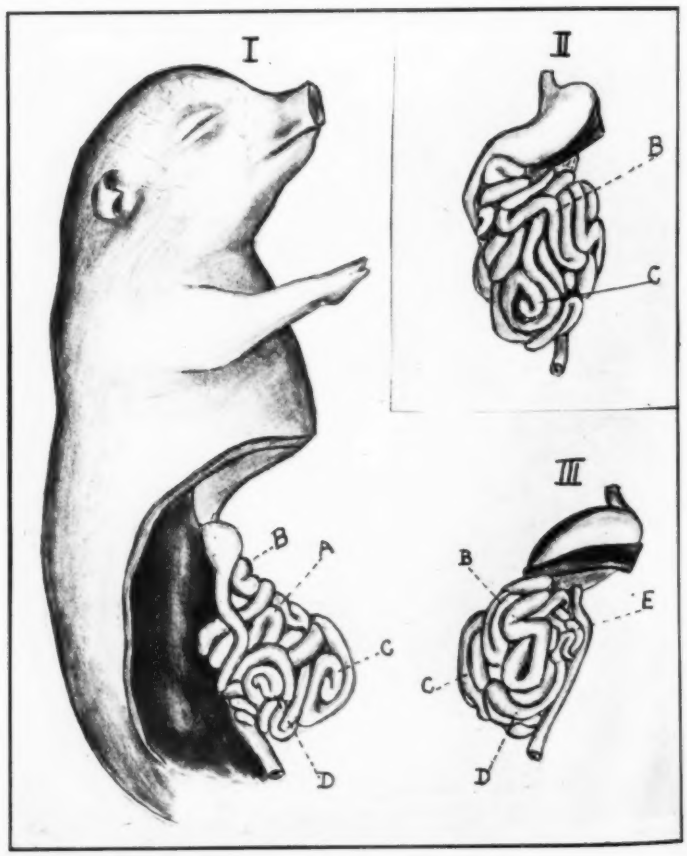


FIG. 16.

MacCallum del.

brain to the cord, and various theories were brought forward to explain it. It was considered probable by some anatomists that the pyramidal tract divided at the decussation, some fibres passing to the lateral column of each side, while a portion remained in the anterior column as the direct tract; but in the absence of confirmation Sherrington's theory of "recrossed" fibres was generally accepted. Sherrington's conclusions were based upon experimental unilateral lesions on the brain of the monkey, in which he claimed that immediately below the decussation the degeneration was all on the opposite side of the cord, while at a still lower level degenerated fibres were found in both lateral columns. He thereupon assumed that all the degeneration crossed over in the decussation to the opposite side of the cord, but a portion crossed back at a lower level to the lateral column of the same side. The probable explanation of his mistake is that at the time of his observations the delicate methods in use in recent years were not known. Still the fact that he reported at the same time that fibres from the upper limb area of the cortex passed down the entire length of the cord, while fibres from the leg areas disappeared from the cord in the cervical and upper dorsal regions, would indicate that his preparations were handled or studied somewhat carelessly. It is rather curious that no one seems to have suggested that he had mixed up those cords.

Soon after the publication of Marchi's method of staining degenerated nervous tissue by osmic acid, Muratow undertook the study, by that method, of degenerations following lesions of the brain in the dog. He published the results of his observations in 1893[1] and clearly showed that in the dog the pyramidal tract divided at the decussation and a portion passed directly to the lateral column of the same side. I had been working with the same method tracing degenerations in the central nervous system of the monkey after very minute lesions of the cerebral cortex, and at the time of the appearance of Muratow's publication I had already accomplished the same results on the monkey, but to him undoubtedly belongs the credit of priority. These results have since been confirmed by other investigators, and Dejerine and Thomas[2] and Risien Russell[3] have proved the existence of the same conditions in man.

At the same time I was able to demonstrate the passage of fibres from the pyramid of one side directly to the motor nuclei of both sides in the pons and medulla.[4]

The following experiment enlarges still further the scope of bilateral representation and adds another to those paths already demonstrated by which one hemisphere may control more or less both halves of the body. It by no means stands alone, but is presented as the type of a considerable group which will be considered individually in a later publication.

On September 20, 1898, I operated in Mr. Victor Horsley's laboratory at University College, London, on a small but apparently healthy bonnet monkey (Macacus sinicus). The animal being etherized, the cortex of the left hemisphere was exposed under strict aseptic precautions, the centre for thumb movements determined by electrical stimulation and that portion of the cortex carefully excised. Care was taken not so much to remove every portion of cortical substance as to avoid injury to the underlying white matter. I therefore passed the knife under the cortex with the flat surface of the knife parallel to the convexity of the hemisphere, bringing it out at a right angle to the line of incision. Then lifting the cut edge with a pair of small forceps the excision was easily completed. The slight hemorrhage was controlled with hot saline solution, the wound closed with horsehair sutures and dressed with borated cotton smeared with collodion. This monkey got diarrhœa and died on the tenth day after the operation (September 30) of marasmus. The wound in the scalp had healed well and there was no trace of sepsis. The brain and cord were removed, kept for four days in formalin and then transferred to Müller. The brain was cut into thin segments in a plane nearly parallel to the occipital sulcus (Affenspalte), as shown in Figs. 1 and 2, and stained by the Marchi method. It was my endeavor to make the plane of section correspond as nearly as possible to the course of the projection fibres through the internal capsule.

Description of the Lesion.

The portion of cortex removed was circular and about one cm. in diameter. About one-third of the area of the lesion was in the ascending parietal convolution and the other two-thirds in the ascending frontal. Its posterior extremity was about midway between the lowest portion of the interparietal sulcus and the fissure of Rolando, while its anterior boundary was the superior angle of the sulcus precentralis. The lowest portion of the lesion was very nearly opposite the lower extremity of the interparietal sulcus, and it extended upward to the superior frontal sulcus.[4a] The lesion in the ascending frontal was much more shallow than in the ascending parietal and the entire cortical substance was removed only at that portion of the ascending parietal convolution nearest the centre of the lesion, close to the fissure of Rolando. It was at this point that uncomplicated flexion of the thumb was obtained on stimulation with a weak faradic current. The portion of cortex removed became thinner from the centre to the periphery of the lesion. In the hardened brain there was evidence of slight cerebral hernia, *i. e.* bulging of the brain into the opening in the skull, which accounts for the irregularity of contour in Fig. 3.

In Figs. 1 and 2 I have endeavored to show the distribution of association fibres to the external surface of the two hemispheres, the proximity of the oblique parallel lines to each other corresponding to the amount of degeneration found in the various convolutions. It was impossible to

[1] Archiv für Anatomie und Entwickelungsgeschichte. 1893.

[2] Dejerine and Thomas. Archives. de physiol. norm. et patholog. 1896, No. 2. Review in Neurologisches Centralblatt, 1897, p. 503.

[3] Risien Russell. Brain. Summer, 1898.

[4] Proc. Roy. Soc. vol. 58.

[4a] In Fig. 1 the lesion does not extend upward as far as it should. It is better represented in Fig. 3.

represent the comparative amount of degeneration so accurately in the outline drawings of transverse sections of the brain (Figs. 3 to 7 inclusive), because in so small a figure, in order to have the degeneration show at all, it was necessary to exaggerate. Degenerated fibres can be seen crossing in the corpus callosum in all the segments except "E," the most posterior. The distribution of association fibres to the convolutions of the two hemispheres is very nearly equal and quite symmetrical. It extends also upon the internal (mesial)

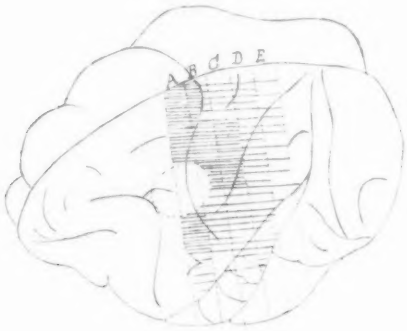


FIG. 1.

surface of both hemispheres as far as the calloso-marginal fissure.

In two segments, C and D, the degeneration extends to the superior temporal convolution of both sides. The route taken by the degenerated fibres to reach the temporal lobe is the same in both hemispheres and is interesting. In section "B" (Fig. 4) a few degenerated fibres appear among the fibres passing to the superior temporal convolution just external to the thickened lower edge of the claustrum on both

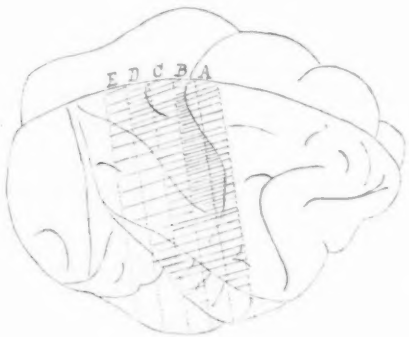


FIG. 2.

sides. In the segment posterior to this (Fig. 5) many degenerated fibres can be seen leaving the internal capsule, breaking through the thin inferior edge of the lenticular nucleus and passing below the claustrum to reach the superior temporal convolution. Some of these fibres probably terminate in the lateral geniculate body. Although no continuous fibres could be traced from the internal capsule into the lateral geniculate body, it lies directly in the path of those running to the temporal lobe and there is considerable degeneration in this nucleus in both hemispheres. Still posterior to this (Fig. 6) degenerated fibres are passing between the islets of gray matter representing the prolongations of the putamen, while many others may be seen passing down among the fibres of the external capsule. The degenerated fibres in the superior temporal convolution are apparently continuous with both these tracts, the course of which is the same in both hemispheres.

Taking into consideration the movements represented in

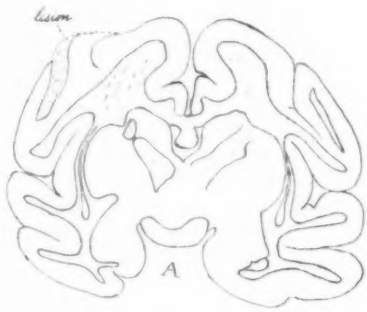


FIG. 3.

that portion of the cortex removed, the distribution of association fibres is of especial interest. While the centre for *uncomplicated* movement of the thumb occupies but a small portion of the area removed, movements of the thumb as part of some associated movement or march may be obtained not only from every portion of that area but also from points considerably removed therefrom—even as far down the convexity of the brain as the lower extremity of the fissure of Rolando. It is a question of much interest whether this is

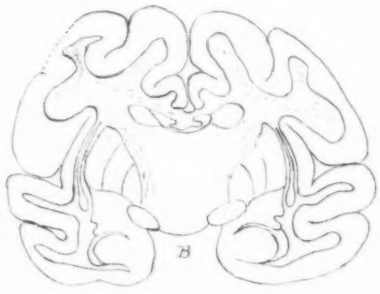


FIG. 4.

brought about by means of association fibres or projection fibres passing directly from each of the widely separated cortical areas to the system of secondary neurons in the cervical region of the cord. It is quite possible that complicated movements may be brought about in either or both ways. The great increase in cortical association tracts between monkey and man suggests the possibility of inconceivable degrees of association.

Looking upon the motor cortex as representing the centres

for associated movements one would naturally expect to find projection fibres passing directly down through the capsule from that part of the cortex, giving rise to the movement. As I understand the significance of excitation experiments upon the cortex, the finding of a centre for the uncomplicated movement of the thumb only means that in the movement represented at that spot, the movement of the thumb (flexion or otherwise) is the first or initial movement of the march. If the stimulation is continued or increased the

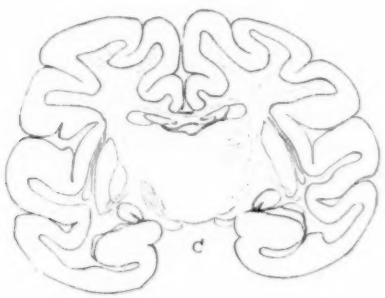


Fig. 5.

march is continued or completed unless interrupted by a general convulsion. Thus, if the anæsthesia is at just the right stage the gentlest stimulus only excites the first or initiatory movement of the march. In opposition to such a theory it may be urged that only one centre has been found in any single animal for such uncomplicated or initial movement, while many combinations are possible beginning with such movement. This would hardly render an entirely separate centre for each movement necessary, as they might all be grouped about the common centre.

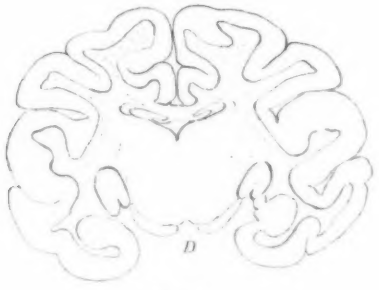


Fig. 6.

In experimental destruction of small cortical areas in the monkey I have often traced projection fibres into the cervical region of the cord from portions of the facial area far removed from arm centres. Such fibres probably represent the conduction paths for impulses, giving rise to movements in which the arm is associated with facial movement. Such movements or actions are numerous in the monkey and increase as we go up in the scale. For example, in feeding, the monkey stretches out his arm, opens the hand to lay hold of the object, which he grasps and carries toward his already opening mouth. In this instance the extension of the arm is the initial movement, followed by extension of the thumb and fingers, then flexion, etc. Such a movement or march is of course much more complicated than any movement obtained by electrical stimulation of the cortex. But it must be assumed that the normal discharge of energy from the cells concerned in the cortical reflex, as a result of incoming sensations, is a very different affair from our experimental stimulation. Stimulation of the motor cortex with a weak faradic current gives rise to certain movements. Cut away the cortical cells and stimulate the cut ends of the projection fibres immediately beneath and you get the same result. Who can say these results are or are not brought about in the same way? Does the former experiment induce a discharge of energy from the cell or does the current passing through the cell to the axis cylinder act exactly as in the other instance? However this may be we cannot safely assume that stimulation experiments disclose more than a hint of the functional activity of the cortex.

A study of the excitation experiments of Beevor and Horsley[5] on the bonnet monkey shows that they obtained from

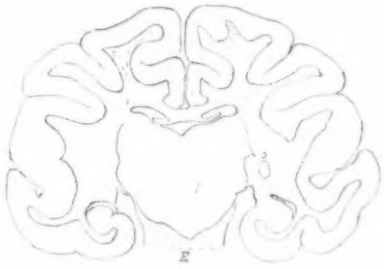


Fig. 7.

the cortical area corresponding to the lesion in this experiment:

Movements of thumb of the opposite side; flexion, extension and adduction;

Flexion and extension of the fingers, opposite side;

Movements of wrist, elbow and shoulder, opposite side;

Closure of opposite eyelids;

Turning of the head to the opposite side;

Retraction and elevation of the corner of the mouth, opposite side;

Pouting, pursing and rolling in of the lips, more of the opposite side, but often bilateral;

Opening of both eyes and

Retraction of the head.

The last two were each observed only once in fifteen experiments. These movements were obtained from various points within the given area but in no single animal were they all observed, nor was any one of these movements obtained from exactly the same point in all the animals experimented upon. Most were primary, though sometimes secondary or tertiary.

[5] Beevor and Horsley, Phil. Trans. Royal Society, B. 1887 and 1894.

No purely primary movement was observed of the elbow or the fingers.

On stimulation of the cortex of the orang outang the same investigators[6] observed opening of the eyes and turning the head and eyes to the opposite side represented in the same area, or rather in that part of it anterior to the fissure of Rolando. This march, it will be seen, is also represented within this area in the Bonnet, though not so clearly brought out as in the latter. It is of especial interest in connection with the considerable degree of degeneration found, in the experiment here described, in the superior temporal convolution, now well established as the auditory centre. The association of this centre with that portion of the cortical area which controls the opening of the eyes followed by synchronous movement of the head and eyes would seem to be the anatomical basis of a cortical reflex of primary importance to self-preservation in all wild animals. It is also to be noted that the distribution of these fibres is quite bilateral. The fact that in this case they degenerate toward the auditory centre, instead of from it, may be urged against the supposition that these fibres are a link in this reflex, but the anatomical relations of the two centres are certainly intimate and direct.

The feature of special interest in this group of experiments is the large number of degenerate fibres passing from the area of the cortical lesion over the middle line in the corpus callosum and down the internal capsule of the opposite side.[7] With the exception of those fibres going to the superior temporal convolution of the opposite side, these fibres, in this experiment, all pass into the thalamus. In a few animals, in which practically the same area was extirpated, some of the degenerated fibres found in the internal capsule of the opposite side can be followed through the pons and medulla into the cervical region of the cord where they disappear.

Nerve fibres within the central nervous system usually functionate in the direction of degeneration, but there is nothing in the character of the degeneration to suggest the character of the function. This can only be guessed at by the origin, course and termination of the fibres and what we know of the function of the areas and structures thus anatomically associated. Some of the projection fibres passing inward from the motor cortex clearly carry motor impulses, but it cannot be assumed that all do. A vast number of projection fibres arising in the motor cortex end in the thalamus; I think I may say in the thalamus of both sides. A careful study of the brains of a large number of animals, mostly monkeys, the subjects of experimental lesions of the cortex, leads me to conclude that this anatomical connection of each thalamus with the cortex of both hemispheres is most evident in those instances in which the area excised was that in which movements more or less bilateral are represented. These movements are mostly facial; such as are called into play in the expression of the emotions. May not this have some bearing on the function of the thalamus? It has been suggested that the thalamus is the centre for reflex or emotional movements.[8] In unilateral facial palsy the escape of the emotional paths has long been a puzzle. According to present conceptions the cortex is concerned in all reflexes involving consciousness. Many cortical reflexes are purely voluntary. The part played by volition in those cortical reflexes termed emotional, such as the play of the features in facial expression, is open to discussion, but it can hardly be doubted that they are as much cortical reflexes as any of the so-called voluntary movements. The interposition of the thalamus in such an arc and the anatomical connection of each hemisphere with both thalami, as here demonstrated, may explain the play of the features as the result of emotion when voluntary movement is impossible. In many extensive lesions of the internal capsule fibres passing into the thalamus, even on the side of the lesion, might easily escape injury, even if bilateral control of the thalami were improbable.

As to the functions, other than motor, of projection fibres from the motor cortex, it is at least possible that some serve the purposes of inhibition, voluntary or otherwise. It seems altogether reasonable that voluntary inhibition of certain visual reflexes might be essential to holding the eyes fixed upon a given object. This is suggested as a possible explanation of the presence of degenerated fibres in the lateral geniculate bodies in this case (Figs. 5 and 6). There is certainly no reason why the reflex might not be inhibited in the geniculate body before it reaches the motor oculi nuclei.

[6] Beevor and Horsley, Phil. Trans. Royal Society, B. 1890.

[7] The writer has found the same thing—degeneration in the internal capsule of both sides after unilateral lesion in the brain, in the dog. In the dog all the degeneration in the internal capsule of the opposite side ends in the thalamus.

[8] Bechterew. Leitungsbahnen im Gehirn und Rückenmark. Zweite Auflage.

A NEW CARBON-DIOXIDE FREEZING MICROTOME.

By Charles Russell Bardeen, M. D.,

Associate in Anatomy, The Johns Hopkins University, Baltimore.

The carbon-dioxide freezing microtomes in common use in pathological laboratories have several drawbacks. Of these the most serious are those due to the use of a rubber tube to connect the tank with the freezing stage. In addition to the annoyances due to the rubber tube the microtomes are so constructed as to utilize but a slight fraction of the heat absorption due to the expansion of the liquid carbon-dioxide. In order to obviate these drawbacks the microtome described

below was devised. In the designing of the original machine I had the assistance of Mr. E. F. Northrup. In the construction of the present machine I am indebted to Bausch and Lomb, who manufacture it, for several modifications which have simplified the instrument and rendered it more useful.

Figure 1 shows the machine as it stands ready for use. It is made to screw directly upon the nozzle of the carbon-dioxide tank. The valve of the latter is utilized to control the escape of the gas into the freezing stage. When the microtome is screwed directly upon the carbon-dioxide tank it is necessary that the tank should lie in a horizontal position, on a table for instance, where it may be held in place by some simple clamp. On the other hand, if it is desired to connect the microtome to a tank placed in some other than the horizontal position an L-shaped piece of tubing may be screwed on the nozzle of the tank and the microtome on the other end of the L tube. The tank may then be placed in any position desired.

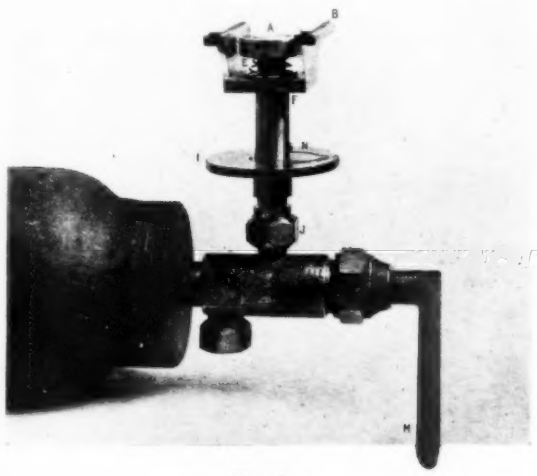


FIG. 1.

A. Cover of freezing stage.
B. Glass track for carrying knife.
E. Spiral spring.
F. Tubal base of knife-stage.
I. Wheel.
J. Nut for attaching axial tube to tank.
M. Handle of tank-valve.
N. Pointer.

The axis and main support of the machine consists of a solid tube with a narrow lumen (*K-D*, Fig. 2). This axial tube is united by a nut (*J*, Fig. 1 and Fig. 2) either to the nozzle of the tank or to the L-shaped tube mentioned above. The machine is thus very readily attached.

On the top of the axial tube the freezing stage (*A*, Fig. 1, *A-C*, Fig. 2) is screwed. This stage piece consists of two parts, a base and a cover. The base is the part screwed into the upper end of the axial tube (*C*, Fig. 2). To this base the cover-piece is screwed (*A*, Fig. 2). Between the base of the stage and the axial tube is placed a thin brass plate (*D*, Fig. 2) with a very narrow aperture at its centre. Through this narrow aperture the carbon-dioxide escapes into the lumen of the stage piece (*C*, Fig. 2). The difference in pressure on the two sides of the brass plate causes a very rapid expansion of gas between the cover and base of the freezing stage. The passage open for the escape of gas from the lumen of the base (*C*, Fig. 2) to the external world is in the form of a spiral passage which finally opens out through the side of the cover, as shown in (Fig. 1, *A*). Between the cover and base of the freezing stage an asbestus washer is placed. The expanding gas therefore can absorb little heat from the base of the stage. Almost all heat absorption must take place from the cover. This heat absorption is greatly facilitated by the metallic spiral which projects down from the cover so as to give rise to the spiral passage through which the gas escapes.

Through the mechanism here described far the greater part of the heat-absorbing power of the expanding gas is utilized

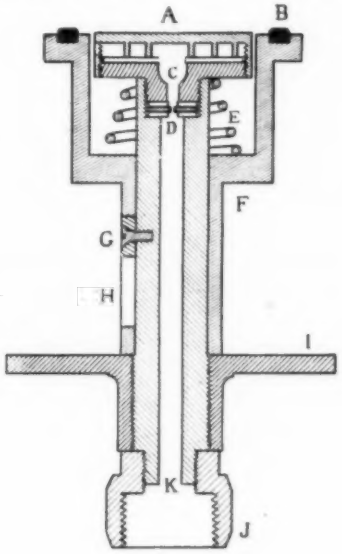


FIG. 2.

A. Cover of freezing stage.
B. Glass track for carrying-knife.
C. Aperture in base of freezing stage.
D. Aperture in thin brass plate.
E. Spiral spring.
F. Tubal base of knife stage.
G. Check for limiting movements of knife-stage.
H. Groove for G.
I. Wheel.
J. Nut for attaching axial tube to tank.
K. Opening into lumen of axial tube.

to lower the temperature of the surface of the cover of the freezing stage. The temperature of the rest of the machine is but little altered. Good control of the temperature of the freezing stage can be thus maintained. This control is farther rendered possible by the valve of the tank. If this valve is turned on full the temperature of the cover of the freezing stage is quickly reduced to a very low point. Tissue placed

on it is quickly frozen. On the other hand, if the gas is not allowed to escape from the tank with full force the difference in pressure in the two sides of the brass plate is less and heat absorption from the cover is less marked. In this way tissues placed on the cover may be slowly frozen without subjecting them to severe cold. Thus, too, a constant low temperature may be maintained by opening the tank-valve to the required point.

The mechanism for controlling the thickness of the sections is equally simple. On the lower end of the axial tube a movable wheel (*I*, Fig. 1 and Fig. 2) is placed. This wheel moves up and down the axial tube on a screw thread cut twenty-five threads to the inch. A complete revolution of the wheel therefore raises or lowers it a millimeter. The margin of the wheel is divided into fifty spaces, each of which therefore represents twenty microns. A pointer (*N*, Fig. 1) serves to indicate the number of spaces passed in a partial revolution of the wheel and thus to show the thickness of the sections cut.

The knife-stage (*F-B*, Fig. 1 and Fig. 2) consists of a tubal base (*F*), which surrounds the axial tube and rests on the movable wheel; and of two flanges (*B*) which extend above the freezing stage on each side for the support of the cutting blade. The base of the knife-stage is moved up the axial tube by screwing the wheel upwards. It is forced down the axial tube by the spring (*E*, Fig. 1 and Fig. 2) whenever the wheel is turned so as to be carried downwards. The flanges of the knife-stage support parallel glass tracks upon which the cutting blade is carried to and fro.

For cutting sections a razor or a plane or almost any good steel blade with a straight edge may be used.

The advantages of the machine are as follows:

1. But little carbon-dioxide is wasted.

2. The temperature of the freezing stage can be controlled.

3. Owing to the nature of its attachment to the tank it can be readily carried about. This should render it of especial value to surgeons.

4. Above all it is simple in design, strong, and unlikely to get out of order.

NOTES ON CERVICAL RIBS.

By Clinton E. Brush, Jr.

(From the Anatomical Laboratory of the Johns Hopkins University.)

Although many cervical ribs have been described heretofore, the following description of three cases is given because of variations presented which, while most of them have already been recorded, are somewhat rare.

Case I. Fig. 1. The dissection of this subject was nearly completed before the cervical rib was noticed, so that most of the soft parts had already been removed before it came to my hands.

There was a cervical rib on each side, the left being much better developed than the right. Each rib was made up of head, neck, tubercle and shaft. Each articulated with the seventh cervical vertebra on the body and on the transverse process. There was a simple stellate ligament at the costo-central articulation, and a capsular ligament at the articulation of the tubercle with the transverse process.

The left rib extended down to the upper border of the first thoracic rib, with which it articulated, being held in position by a capsular ligament. There was a slight articular eminence or facet on the first thoracic rib at the point of articulation, the facet apparently corresponding to the scalene tubercle of a normal first thoracic rib. The left cervical rib projected a distance of 2.3 cm. beyond the body of the seventh cervical vertebra and then curved sharply downwards. The extreme width of the rib was at this point, where it measured 1.6 cm. The shaft of the rib was triangular in cross-section and measured .4 cm. in thickness.

The seventh cervical nerve on the left side crossed the middle of the broad upper half of the rib in a well marked groove.

At a point 2.6 cm. from the distal end of the rib was the superior border of a sharply defined groove, .9 cm. in width. Across this passed the lower trunk of the brachial plexus (1), the eighth cervical and first thoracic nerves uniting before crossing the rib. As the trunk of the brachial plexus was

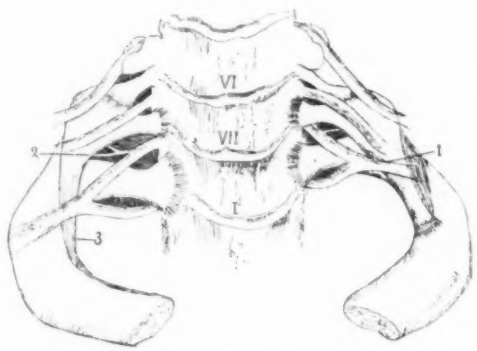


Fig. 1.

Case I.—1. Lower cord of brachial plexus. 2. Supplementary intercostal nerve. 3. Fibrous cord.

but .4 cm. in diameter, it is probable that the subclavian artery also crossed in this groove.

In the supplementary interspace there were some well developed muscle fibres, but their condition was such that it was impossible to decide whether or not there had been both an inner and an outer set. Just before crossing the upper border of the first thoracic rib, the eighth cervical nerve

gave off a small branch (2), which divided into several smaller twigs to innervate the supplementary intercostal muscle.

The right cervical rib corresponded very closely in size and shape to the upper half of the left rib. It extended 1.7 cm. beyond the body of the seventh cervical vertebra and was 1.4 cm. wide. The upper border curved sharply downwards and met the lower border 2.6 cm. below the tubercle, so that the rib ended in a point. From this pointed end a round, fibrous cord (3) extended to the first thoracic rib, meeting it at a point corresponding to the place of articulation of the left cervical rib with the first thoracic rib on the left side. From here the fibrous cord was continued along the superior border of the first thoracic rib to the sternum.

On the right side also the supplementary interspace contained well developed muscle fibres, the nerve supply being similar to that on the left side.

The distribution of the arteries that were still on the subject was normal, except that on both sides the vertebral arteries passed up to enter the foramina of the transverse processes of the fifth cervical vertebra.

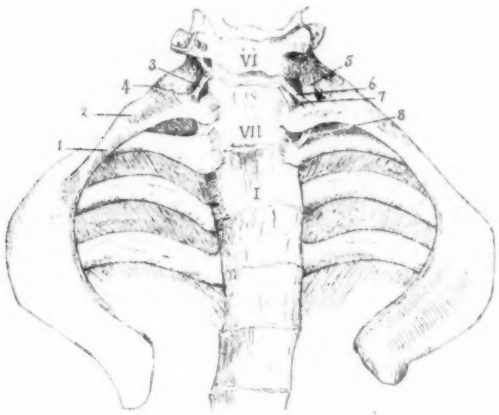


FIG. 2.

CASE II.—1. Groove for subclavian artery and lower cord of brachial plexus. 2. Groove for VII cervical nerve. 3. Ligament. 4. Capsular ligament. 5, 6, 7 and 8. Ligaments.

CASE II. Negro woman. Age, about 60 years. Fig. 2. Vertebral formula— *C*, 7; *T*, 12; *L*, 5; *S*, 5.

This subject possessed two well developed cervical ribs, that on the left side being much better developed than that on the right. Each rib consisted of head, neck, tubercle and shaft. Each articulated with the seventh cervical vertebra in two places—the body and the transverse process. The right rib articulated with the superior border of the first thoracic rib, 6.9 cm. from the head of the latter. The left rib was ankylosed with the superior border of the first thoracic rib, the central point of the ankylosis being 5.5 cm. from the head of the thoracic rib.

The general shape of the two ribs was the same, the upper part of the shaft being broad and flat and then rapidly narrowing down to a shaft which was triangular in cross-section. Each rib presented two grooves. One (1) which was very well defined, was on the anterior surface of the narrow part of the shaft for the passage of the lower trunk of the brachial plexus and the subclavian artery. The other groove (2) was very slight and extended outward across the broad upper part of the shaft for the passage of the seventh cervical nerve.

The diameter of the first thoracic rib on the left side from its head to the ankylosis with the cervical rib, but more especially in the neck, was much less than that of the right thoracic rib in the same part. Beyond the ankylosis it was about the same width as the right rib was beyond its articulation with the cervical rib.

From the tip of the right cervical rib a round fibrous cord extended to the sternum along the superior border of the first thoracic rib, being closely adherent to the latter. A similar cord was present on the superior border of the left thoracic rib, being continued from the ankylosis.

The principal measurements of the ribs were as follows:

	Right.	Left.
Head, neck and tubercle	2.6 cm	2.8 cm.
Straight line from back of tubercle to end of rib	4.7 "	4.5 "
Length along concave border	5.7 "	6.6 "
Breadth of upper part of shaft	1.3 "	1.5 "
Diameter of lower part of shaft	.4 "	.6 "
Diameter of neck of first thoracic rib 1 cm. from its head	.95 "	.55 "

On the right side, the scalenus anticus had a normal origin, but was inserted on the tip of the cervical rib and on the superior border of the first thoracic rib for 1 cm. anterior to the articulation of the two ribs. The scalenus medius was inserted along the superior border of the cervical rib from the tubercle to the upper border of the groove for the subclavian artery and lower cord of the brachial plexus, 2.3 cm. from the distal end of the rib. At the lower end of the insertion some of the fibres were prolonged downwards across the inner surface of the supplementary interspace to be inserted on the upper border of the first thoracic rib for 1.1 cm. posterior to the articulation with the cervical rib. The scalenus posticus was inserted on the outer border of the cervical rib at a point 1.6 cm. from the tubercle, in connection with the scalenus medius, and thence by a fibrous band, .3 cm. wide, backward and downward to the superior border of the first thoracic rib for a distance of .5 cm. on that rib.

The supplementary interspace on the right side was filled by two well developed intercostal muscles, an outer and an inner. The external intercostal arose from the outer inferior border of the cervical rib from the head to the extreme end of the rib. The fibres extended downward and forward to be inserted along the superior border of the first thoracic rib. The fibres arising from the end of the cervical rib spread out in a fan-shaped insertion along the anterior face of the first thoracic rib for a distance of 2.5 cm.

The internal intercostal muscle arose from the inner border of the inferior surface of the rib, the fibres running downward and backward to be inserted along the inner border of the first thoracic rib for a similar distance. This muscle was

innervated by fibres from the intercostal branch of the first thoracic nerve. This branch ran along the superior border of the second thoracic rib and sent its fibres across the first rib to the supplementary intercostal muscle.

The eighth cervical and first thoracic nerves united at the inner border of the cervical rib to form the lower trunk of the brachial plexus, which crossed the rib above the subclavian artery. Just before uniting with the eighth cervical nerve, the first thoracic gave off a slender branch which descended along the inner border of the rib, behind the subclavian artery, to the lower end of the rib, where it turned upward to gain the surface, wound around the end of the rib and was distributed to the articular ligament.

The right rib articulated freely with the seventh cervical vertebra and also with the first thoracic rib. A stellate ligament held the head of the cervical rib to the vertebra. Besides this ligament there was a superior costocentral ligament (3) passing from the superior surface of the neck of the rib mainly to the lower outer border of the body of the sixth vertebra, a small slip being continued upward and outward to the anterior inferior border of the transverse process of the same vertebra. A capsular ligament (4) held the tubercle of the rib to the transverse process of the seventh vertebra.

The disposition of the soft parts of the left side was very similar to that of the right. The scalenus anticus was inserted by a fan-shaped set of tendinous fibres to the lower half centimeter of the cervical rib, and was continued along the superior border of the first thoracic rib for 1.6 cm. anteriorly. The scalenus medius was inserted along the superior external border of the cervical rib from its head to the upper margin of the groove for the subclavian artery, 2.3 cm. from the central point of the ankylosis. The scalenus posticus was inserted on the superior border of the first rib. The iliocostalis dorsi sent a slip of insertion to the external border of the cervical rib and also one to the tubercle. On the right side the slip to the tubercle alone was present.

The external intercostal muscle in the supplementary interspace was well developed. It arose from the outer border of the inferior surface of the cervical rib from its head to the ankylosis. The fibres, running downward and forward, were inserted along the superior border and external surface of the first thoracic rib for a somewhat longer distance. The internal intercostals arose from the inner inferior border of the cervical rib, from the ankylosis to the tubercle, and extended downward and slightly backward to be inserted for a similar distance along the superior inner border of the first thoracic rib. The innervation of the supplementary intercostals was similar to that on the right side—by branches from the first intercostal nerve.

The left cervical rib articulated freely with the seventh cervical vertebra, but was firmly ankylosed with the superior border of the first thoracic rib, the ankylosis covering a distance of 2.2 cm. The tubercle articulated with the transverse process of the seventh vertebra, the joint being effected by a capsular ligament, no distinct division into smaller individual bands being noticeable. From the neck of the rib, just within the tubercle, a fibrous band (5) .5 cm. in width extended upward, backward and slightly inward to the lower posterior border of the transverse process of the sixth vertebra, and to the anterior face of the transverse process of the seventh. A small ligament (6) connected the superior external margin of the head with the lower, outer border of the body of the sixth vertebra. Just internally to this, and arising from the middle of the superior surface of the head, a band .3 cm. wide (7) extended upward and inward to the lower outer border of the sixth vertebra, the insertion being under and inside of that of the smaller slip. Posteriorly to these, another ligament, .6 cm. wide, connected the superior posterior surface of the head with the lower border of the body of the sixth vertebra. A short, tough, fibrous cord (8) extended from the inferior surface of the head of the cervical rib to the superior surface of the head of the first thoracic rib. From the upper half of the head of the cervical rib a stellate ligament extended to the body of the seventh vertebra.

The arterial distribution on both sides was normal except for the origin of the left common carotid from the innominate artery immediately after the latter left the aorta.

There was a distinct skoliosis to the left side in the upper thoracic region.

Case III. This was simply a cleaned specimen of a rib from the anatomical museum. Nothing was known about the subject from which it came.

The specimen was that of a left first thoracic rib, having a cervical rib ankylosed with it. The ankylosis was so complete and the free part of the cervical rib so short that it would be better to class this as a bicipital first thoracic rib. Its morphology is very similar to that of the bicipital ribs described by Turner.[1] The rib presented two heads, two necks, two tubercles; and, for a distance of 1.6 cm. beyond the tubercle of the upper division, there were two shafts. That point marked the posterior limit of the ankylosis, which extended forward a distance of 4 cm. On account of the ankylosis, the rib was very broad at this part, being 2.6 cm., while the true shaft of the first thoracic rib beyond the fusion was but 1.7 cm. The two necks were separated by a space .6 cm. wide.

The principal measurements of the rib were as follows:

From tip of head to outer border of tubercle, (upper division).	3.4 cm.
" " " " " " (lower division).	3.6 "
Width of neck, (upper division)	.8 "
" " (lower division)	.7 "
Straight line from head of lower division to distal end of rib.	8.5 "
Length along convex margin from head of lower division to distal end of rib	19.2 "

The upper border of the rib presented two grooves, one crossing just anterior to the central point of the ankylosis and the other .7 cm. anterior to this. In the recent state the subclavian artery and lower cord of the brachial plexus undoubtedly crossed by the former, while the latter was prob-

[1] Journ. Anat. and Physiol., 1883, vol. xvii, pt. iii.

ably for the passage of the subclavian vein. Between these two grooves there was a very prominent pointed process, projecting 1 cm. beyond the upper border of the rib. The anterior margin of its base was also the anterior limit of the ankylosis. From its general direction and from the fact that there was a visible groove along the line of ankylosis, it seems probable that this represented the tip of an originally free cervical rib. In the recent state there was probably a fibrous cord extending from the tip of the process to the sternum.

Summary.

Of these three cases, the first two present some uncommon variations. In the first case the innervation of the supplementary intercostals by a direct intercostal branch from the eighth cervical nerve has been described only once.[2] The second case shows a peculiar insertion of the serratus posticus on the first thoracic rib. This has also been described by Gruber,[3] but it is not mentioned as a variation in the standard text-books, nor is it spoken of by Le Double.[3] This case also presents the following variations, which, so far as I can find, have not been reported heretofore: a minute branch from the right first thoracic nerve to the articular ligament between the cervical and first thoracic ribs; a ligament connecting the head of the left cervical rib with the head of the left first thoracic rib, and a ligament from the neck of the cervical rib to the lower border of the transverse process of the sixth vertebra (Fig. 2, 5). For a full list of references to the subject of cervical ribs the recent article by Phillips[4] may be consulted.

In conclusion I wish to express my thanks to Dr. R. G. Harrison, at whose suggestion the work was originally undertaken, for his advice and assistance in my work.

[2] Mem. de l' Acad. des Sc. de St. Petersbourg, 1869.

[3] Traité des variations des Systéme masculaire de l' homme. Paris 1897. Tome I.

[4] Journ. Anat. and Physiol., 1900, vol. xxxiv, n. s. xiv, pt. iv.

ON THE PRESERVATION OF ANATOMICAL MATERIAL IN AMERICA BY MEANS OF COLD STORAGE.

By Abram T. Kerr, B.S., M.D.,

Assistant Professor of Anatomy, Cornell University, Ithaca, N. Y.

The preservation of the dead body and its preparation for dissection have always been problems to the teacher of anatomy. The methods of preservation are different according to the object in view; certain methods being employed when it is only desired to keep the body for the ordinary dissection; others, when special parts, systems, or regions are to be worked out; and still different methods when it is desired to store material for months or years. One great step was made in the process of preservation of anatomical material for dissection when Frederic Ruysch, the Dutch anatomist, introduced the method of embalming by means of injection. This was further developed by William Harvey and has been brought to great perfection at the present day both by the anatomists and the professional embalmers. The various methods employed in most of the principal European schools have been carefully described by Dr. Hjalmar Grönoos in the Anatomischer Anzeiger for September 28, 1898; and a report upon the various methods employed in America was prepared by a committee of the Association of American Anatomists and published in *Science* January 17, 1896.

The rapid development of medical education has called for the introduction of more laboratory work in the first two years of the course, and this, together with the increased tendency to concentrate medical teaching in the larger colleges, has made it necessary to collect dissecting material during the whole year and to develop methods which shall preserve it in good condition until wanted.

The method of pickling, that is, placing the body after it is embalmed and injected into a large vat of brine or some other fluid, is being quite generally abandoned. It is replaced in some institutions by enclosing the bodies in tightly sealed boxes, in which there is an inch or more of alcohol on the bottom and the body is surrounded by alcohol vapor. In other places the use of cold is employed to keep the bodies until they are needed.

Cold is produced according to the well known law of physics, that heat is required to change a solid into a liquid, or liquid into a gas. This heat is abstracted from surrounding substances. For the preservation of cadavers the cold was produced until the past few years by the melting of ice, either alone or combined with salt. But within recent years refrigerating machinery has been so well perfected, and the cost of these machines has been so much reduced, that to-day there are ten medical colleges in the United States which have installed refrigerating plants. The principle on which these machines work is very simple. It is well known that it requires much more heat to vaporize a liquid than to liquefy a solid; thus to liquefy 1 gram of ice it requires 80 heat units, but to vaporize 1 gram of water it takes 537 heat units. Therefore in the freezing machine a volatile liquid such as ammonia or ether is used. The machines on the market to-day are mostly ammonia machines.

The first ice machine to be used to preserve dissecting material was installed by the College of Physicians and Surgeons, Columbia University, New York, and when it had been in operation long enough to show the practicability and advan-

tages of this method plants were installed by the Johns Hopkins and by the University of Pennsylvania and later by Syracuse University, Long Island College Hospital, the University of Buffalo, Jefferson Medical College, the University and Bellevue Hospital Medical College, Cornell University Medical College, New York City, and a plant is to be built this year by the Cornell University Medical College at Ithaca, N. Y.

Last April, at the suggestion of Dr. Mall, I presented before the Association of American Anatomists at Washington a very brief account of the plant installed at the University of Buffalo. At this time I wrote to the professors of anatomy in all the institutions where I knew that they had cold storage plants and asked for certain statistics in order to compare their results with those obtained by me at the University of Buffalo. From some of these which I am permitted to use, and from the articles of Dr. Mall[1] on the cold storage plant at the Johns Hopkins, and of Dr. Holmes[2] on that at the University of Pennsylvania, I wish to call attention to those things which it is desirable to incorporate in a plant and those which should be avoided. I desire at this point to express my thanks to the professors in the institutions named above for furnishing me with data regarding the ice machines and vaults employed by them.

There are two systems in use at the present day. In the ammonia-absorption system a solution of ammonia in water is heated, the ammonia gas passes off into a condenser where the constant distillation raises the pressure and the heat being absorbed by a stream of cold water, the ammonia becomes liquid. The liquid ammonia is conducted to the refrigerating coils, where it again becomes a gas and by thus vaporizing produces cold. The gas then passes to another chamber, where it is absorbed by a weak solution of ammonia in water, and the strong solution resulting is returned to be heated again. This type of apparatus is said to have some advantages over the other system, as its relative cheapness and lack of complicated machinery, but it is also deficient in several respects. The Long Island College Hospital is, I believe, the only medical school which has an apparatus of this kind.

The ammonia compression machine is the one most generally used to-day. This consists essentially of three parts, as shown in the figure of the plan at the Johns Hopkins University. The evaporating coils are the pipes in which the liquid ammonia changes to a gas and absorbs heat from its surroundings. The compressor is a combined suction and compression pump which draws the ammonia vapor from the evaporating coils and forces it under pressure into the cooling coils. These are long lines of pipes immersed in running water, and under the combined action of the pressure from the pump and cold from the water the ammonia gas is here reconverted into a liquid and passes again into the evaporating coils. The flow is of course regulated by valves and pressure gauges. The compression machines are utilized in two

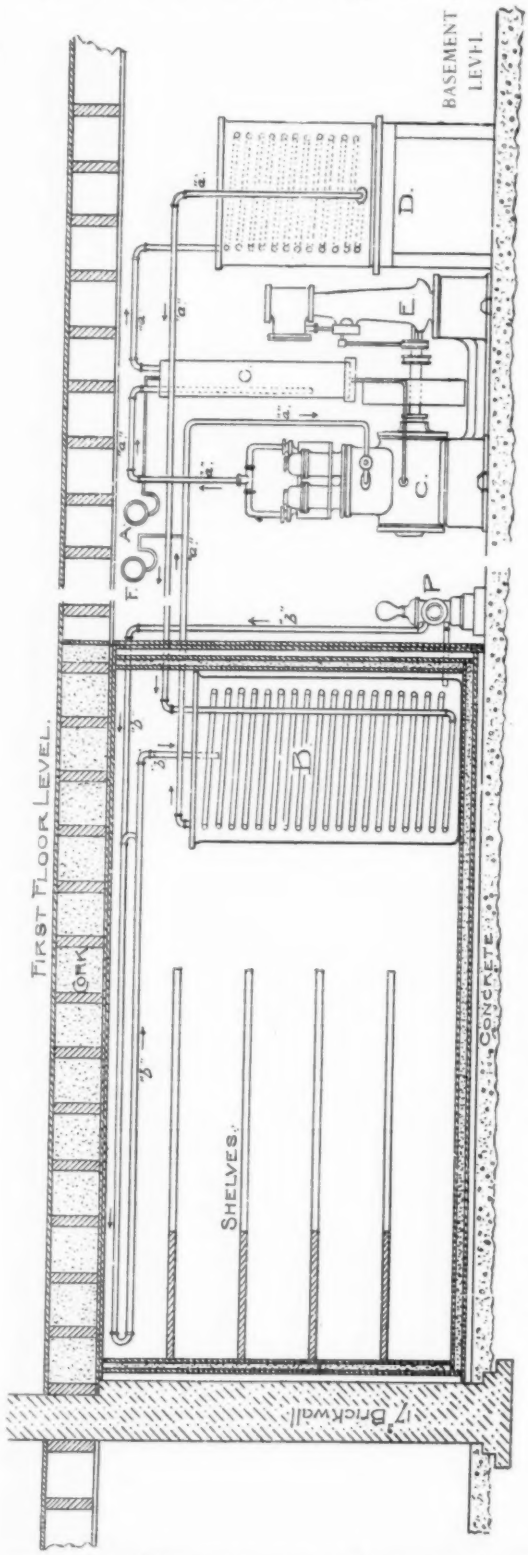


FIG. 1.—Section of the cold storage apparatus and vault at the Johns Hopkins University (after Mall). *C*, Compressor; *D*, Condenser; *O*, Oil Separator; *E*, Engine; *P*, Pump; *B*, Brine; *A*, Pressure Gauge; *F*, Back Gauge; "*a*," Ammonia Pipe; "*b*," Brine Pipe.

[1] Franklin P. Mall, The Anatomical course and Laboratory of the Johns Hopkins University, Bulletin of the Johns Hopkins Hospital, Baltimore, May and June, 1896, vol. vii, Nos. 62–63.

[2] E. W. Holmes, Refrigeration as a means of preservation of Bodies for use in the Dissecting room, Internat. M. Mag. Phil., 1897, vi, 747–749.

ways. In the one the evaporating or expansion pipes are distributed directly in the room which it is wished to cool; in the other these coils are distributed through calcium chloride brine and the cold brine is pumped through the rooms which it is desired to refrigerate. The first of these is known as the direct-expansion method, the other as the indirect. Johns Hopkins and Syracuse have the indirect and Pennsylvania and Buffalo the direct.

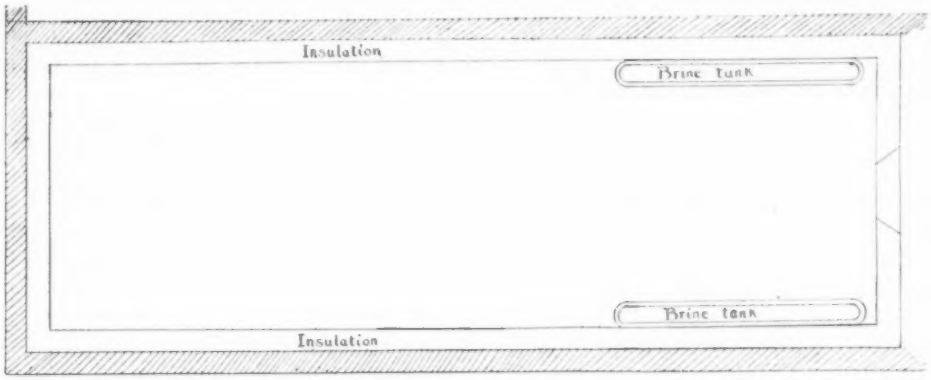


Fig. 2.—Outline of the cold storage vault at the University of Pennsylvania. The brick wall on the outside is striated.

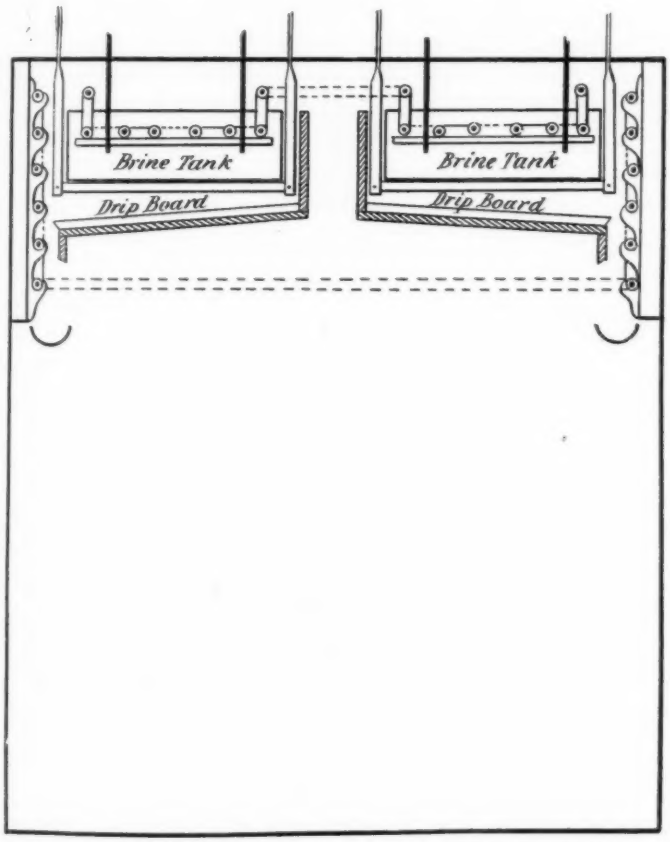


Fig. 3.—Section of the cold storage vault at the University of Buffalo.

Machines are rated in two ways, according to their ice-making capacity, and their refrigerating capacity. The latter is usually taken as twice the former. The unit of ice-making capacity is one ton of ice at 32 degrees F. frozen from water at 32 degrees F., and is equivalent to 284,000 heat units per 24 hours.

It is quite important to get a machine large enough for the work required of it. The size will be influenced greatly

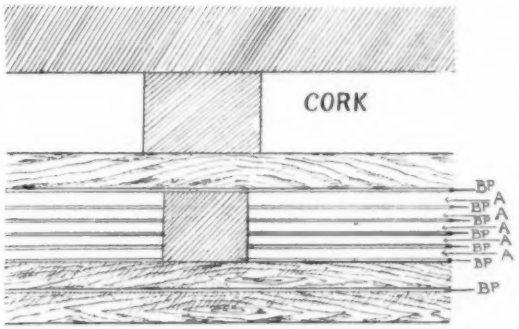


Fig. 4.—Section of the wall and insulation of the vault at the University of Pennsylvania. *BP*, one layer of building paper; *A*, half-inch air space.

by location, insulation, and so forth. Very satisfactory work is being done at Syracuse by a machine of 3 tons refrigerating capacity for a vault of about 3000 cubic feet. At Buffalo a 3-ton machine for about 1500 cubic feet, at Johns Hopkins a 4-ton machine for 2300 cubic feet, at Pennsylvania a 6-ton is used for about 4300 cubic feet. The cost of such a plant varies from $2000 to $3000.

Whether the machine works on the plan of direct radiation or indirectly by means of brine, it is a very great advantage to have within the vault a considerable body of brine which is cooled when the machine is running and which holds the cold, giving it out gradually and keeping the temperature of the vault from rising rapidly when the machine is not running. These brine tanks are cooled by coils of ammonia expansion pipes running through them. In the Johns Hopkins plant, where this device was first introduced, there is one large tank situated in one corner of the vault. Since they use the indirect method this tank alone is cooled by ammonia expansion coils and the cold brine is taken from the tank and pumped through the pipes in the vault. At the University of Pennsylvania there are two long, narrow tanks situated on each side of the door. The brine is not pumped from these, but they simply act as a reservoir for cold brine. At the University of Buffalo there are two long, shallow brine tanks, which are suspended, covering the whole top of the vault. The advantage in this arrangement is that the large mass of chilled brine cools the air above; this falls to the bottom of the vault replacing the warmer and lighter air there, and in this way a constant circulation is kept up (Figs. 1, 2 and 3).

Besides the expansion pipes in the brine, there is a considerable amount of pipe in the vault to cool the air directly. The arrangement of ammonia expansion coils is usually around the sides of the upper part of the vault or along the ceiling, or both. This also helps the circulation and prevents a warmer stratum of air from collecting above and a cold stratum below. The circulation of the air in the vault is only maintained during the running of the machine, as the temperature of the expansion pipes soon becomes the same as that of the surrounding air when the machine is shut down.

The size of the machine required is of course influenced greatly by the size of the vault and its insulation, and the number of hours per day which the machine is in operation. In all of the above-named plants there is more than enough cold produced. The excess of cold can be used to cool some of the dissecting rooms in summer, as is done at Columbia and at Cornell, N. Y.

The construction of the vault is one of the most important

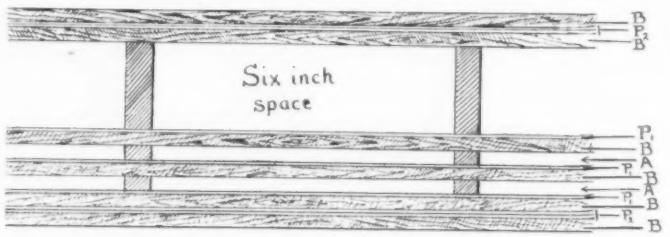


FIG. 5.—Section of the insulation of the ceiling of the vault at the University of Buffalo. *B*, Boards ¾-inch thick; *A*, air space one-inch wide; *P*, building paper.

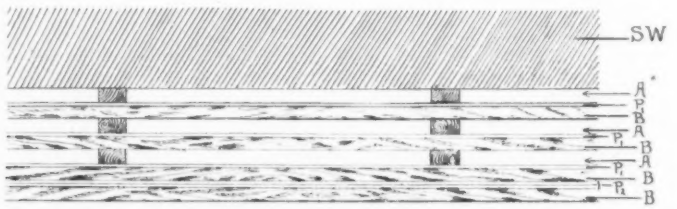


FIG. 6.—Section of the insulation of the side walls of the vault at the University of Buffalo. *SW*, stone wall; *P*, building paper.

things and the aim should be to get the insulation as perfect as possible. With a perfect insulation there will be absolutely no loss of cold and a temperature once obtained will be retained indefinitely. Of course a perfect insulation cannot be secured, but a little extra expense in the construction of the vault at the start is a saving in the end, as the machine will have to be in operation for a much shorter time. The illustrations show the method of insulation employed at the University of Pennsylvania and the University of Buffalo. These consist of a number of dead air spaces separated by boards and building, or tar paper. Some of these air spaces may be filled with cork or mineral wool. With the considerable changes in temperature and consequent expansion and contraction the insulation is liable to be destroyed. This may be partly overcome by having around the outside a strongly braced wall, or one of brick or stone, as at the University of Pennsylvania and the University of Buffalo. It is

important that the floor should be well insulated and covered on the inside with a layer of Portland cement, asphalt or, better still, sheet zinc, which should extend up for a foot or so on the side walls of the vault. It is desirable also that the floor should slope toward the entrance, so that when the machine is shut down and the vault is being cleaned, the water will flow through the door to a drain placed in the room outside.

With a vault of a given size the capacity in bodies varies according to the method of storing them. There are three methods in general use in the different universities. The most popular is to have the vault arranged with a series of shelves. This is the method employed at the Universities of Buffalo, Pennsylvania, Syracuse and Long Island College Hospital. At the Johns Hopkins the bodies were first stored on shelves but in order to increase the capacity of the vault the shelves were removed and the bodies piled one upon another. At Columbia and Cornell, N. Y., they are suspended. There are certain advantages in each system. The method of shelving the bodies takes up the most room, but it has the advantage that each body is easily accessible. The shelves may be divided into sections and each shelf numbered, then when a body is placed in the vault the record of its position can be added to the department history and it can readily be found when desired for a particular purpose. In actual practice this works out very nicely, as employed at the University of Pennsylvania, and a body which has been stored for months and is then claimed by relatives is easily located. The shelves may be either made of slats or solid boards. The latter are used at the University of Buffalo. Where the subjects are piled one upon the other there are several advantages as well as disadvantages. First of all there is great economy of space, and the subjects being packed closely tend to prevent evaporation, but on the other hand there is a tendency for the bodies to become frozen together, causing considerable annoyance when one is to be removed. This has been overcome by Dr. Mall by placing a layer of building lathe between the bodies after they have been vaselined and wrapped. Of course in a great pile of bodies it is very difficult to find any particular one. Bodies packed in this way tend to hold the cold for some time, so after the machine is shut down and the vault thrown open it takes several days for them to thaw out. If these bodies are piled closely around a brine tank it is still more difficult to thaw them with the additional cold from the tank, and this is a great advantage in case of a break-down.

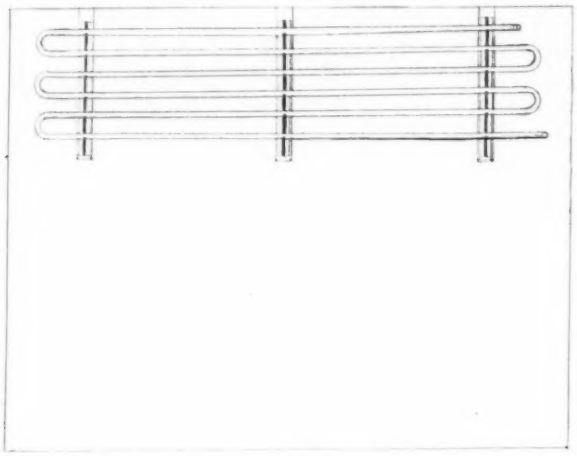


Fig. 7.—Side of vault showing the arrangement of the expansion pipes at the University of Buffalo.

At Columbia and at Cornell, N. Y., the bodies are suspended and run into the cold storage vault on tracks like the carcasses at a slaughter-house. I do not know the advantages and disadvantages of this method.

The temperature in the vault should not be allowed to run above freezing, as this permits thawing, and in consequence a sloppy condition of the floor. The average maximum temperature usually maintained at the University of Pennsylvania is 24 degrees and the minimum 16 degrees Fahrenheit, and at the University of Buffalo the maximum is 25 degrees and the minimum 14 degrees Fahrenheit. This is computed from the daily temperatures for June, July and August, 1899, which are given in the appended table. These temperatures are taken at the University of Buffalo by an ordinary thermometer, it being necessary to enter the vault to take the readings. At the University of Pennsylvania a self-recording thermometer takes the temperature variations.

All of the vaults are lighted by electricity, which may be turned on by a switch from the outside before entering the vault. The cost of operating a plant varies greatly, depending on the size, number of hours a day it is run, number of subjects, and also the motive power.

Steam is employed to operate the machine at the Johns Hopkins and at the Long Island College Hospital, and steam with electricity as reserve at Syracuse University. Electricity alone is used at the University of Pennsylvania, and a gas engine at the University of Buffalo. As the steam is also used for heating and the electricity for lighting it is difficult to estimate the exact amount of either used for running the machine. At the University of Buffalo and at the Johns Hopkins an estimate of the cost for one year was below $100.

In all the cases before the body is placed in the cold room it is embalmed and the arteries filled with colored plaster, starch or at the Johns Hopkins with shellac. When wanted the body has only to be taken from the vault to the dissecting room and upon thawing it is ready for work. When a body is kept in cold storage for a time there is considerable drying of the hands and feet, face and genitals, and when kept for a long time there is a general mummification of the body. To overcome this the body is covered at the Johns Hopkins with a layer of vaseline, over which is wrapped a layer of toilet paper, and the whole is covered with cheese-cloth. The same method is employed at the University of Pennsylvania. At the University of Buffalo and at Syracuse University only the head, limbs and genitals are wrapped.

Although there are other methods of preserving the body

for dissection, it would seem that a well embalmed body properly wrapped and kept in cold storage furnishes the cleanest, best preserved and most satisfactory dissecting material. Besides being used to preserve cadavers the refrigerating plants in the different medical schools are used to keep such material from the slaughter-house as is used for dissection. Fresh organs from post mortems are also preserved in the vault until wanted, or a separate compartment, cooled by the same machine, is built to contain them.

From the study of the various cold storage apparatuses for the preservation of anatomical material it appears that the system at the Johns Hopkins is the most economical, as it does not require continuous operation of the machine. This system is further improved at the University of Pennsylvania and at the University of Buffalo for the direct system of cooling the vault at the same time the brine tank within the vault is chilled makes the pumping of brine unnecessary.

TABLES OF RESULTS OBTAINED DURING JUNE, JULY AND AUGUST, 1899 AT THE UNIVERSITY OF BUFFALO.

The machine was operated only during the day, the numbers below 12 are A. M., and those after 12 are P. M. The temperature is given in degrees Fahrenheit.

Date.	Duration of Run.	Time.	Maximum Temp.	Time.	Minimum Temp.
1899.					
June 1	4 hrs.	10	24°	1	16°
2	3	10	22	1	14
3	3¼	9	22	12	12
4	3	9	26	12	16
5	2¾	9	24	12	14
6	3	9	24	12	14
7	3	9	24	12	14
8	2¾	9, 15	24	12	14
9	2¾	9, 15	24	12	15
10	4	8	23	12	12
11	Sunday.				
12	3¼	8, 45	28	12	17
13	2¼	8, 45	26	11	12
14	3	9	26	12	16
15	3¼	8, 50	26	12	16
16	3	8, 45	26	12	16
17	4¼	8	24	11	13
18	Sunday.				
19	3	9	29	12	17
20	3¼	9	26	12	16
21	3¼	9	25	12	17
22	3¼	9	26	12	17
23	3¼	9	24	12	14
24	3	8	24	12	14
25	Sunday.				
26	3	9	30	12	19
27	3	8	28	12	16
28	3¾	8	26	11	15
29	4	8	26	12	15
30	Engine out of order.				
July 1	4½	8	31	12	14
2	Sunday.				
3	4⅛ and 3	8	31	12 and 5	18 and 13
4	Holiday.				
5	4	8	28	12	18
6	3⅝	8	26	12	16
7	4⅛	8	26	12	16
8	4⅜	8	25	12	15
9	Sunday.				
10	3	8	30	11	18
11	3¼	8	27	11	16
12	3¼	8	26	12	15
13	3⅛	8	27	12	15
14	3⅜ hrs.	8	24°	12	15°
15	4½	8	25	12	15
16	Sunday.				
17	3¼	8	29	12	17
18	3½	8	28	11	17
19	4¼	8	26	12	15
20	4	8	24	12	14
21	3¼	8	24	11	17
22	4	8	25	12	14
23	Sunday.				
24	4	8	29	12	18
25	3½	8	28	12	16
26	3½	8	26	12	14
27	3¾	8	26	12	16
28	3⅝	8	26	12	15
29	4	8	24	12	13
30	Sunday.				
31	3¼	8	28	11	18
Aug. 1	4	8	27	12	17
2	4	8	26	12	15
3	3¼	8	24	11	14
4	4¼	8	25	12	17
5	4	8	25	12	13
6	Sunday.				
7	4	8	28	12	16
8	3¾	8	26	12	15
9	3⅝	8	25	11	15
10	4	8	25	12	13
11	4½	8	24	1	12
12	4¼	8	22	12	10
13	Sunday.				
14	3¾	8	28	12	16
15	4	8	26	12	15
16	3¾	8	24	12	14
17	3½	8	24	11	13
18	4½	8	23	12	12
19	4	8	22	12	10
20	Sunday.				
21	4	8	26	12	15
22	4	8	25	12	15
23	4¼	8	23	12	12
24	3¾	8	23	12	12
25	3¾	8	22	11	12
26	3½	8	22	12	12
27	Sunday.				
28	3¾	8	27	12	17
29	4	8	25	12	16
30	4½	8	25	12	14
31	4½	8	24	12	12

TEMPERATURE RECORD ANATOMICAL VAULT MEDICAL DEPARTMENT UNIVERSITY OF PENNSYLVANIA.

The temperature is given in degrees Fahrenheit.

Date.	Duration of Run.	Maximum Temp.	Minimum Temp.
1900.			
Aug. 26	8 hrs.	5°	3°
27	12	9	4
28	10	10	3
29	10	10	5
30	9	11	5½
31	8	11	8
Sept. 1	11	12	6
2	10	14	8
3	11	11½	7
4	10	12½	6½
5	10	12½	8
6	9	13½	9
7	10	13½	8
8	9	13	9
9	8	14	8
10	7	14	11
11	10	15½	10
12	10	15½	10½
13	9	15½	9

Date.	Duration of Run.	Maximum Temp.	Minimum Temp.
1900.			
14	5 hrs.	14½°	7°
15	8	13	7
16	6	14	9
17	0	15	15½
18	15	16	8
19	13	11	5½
20	10	9	5½
21	9	13½	10
22	7	16	10½
23	9	16	9
24	9	15	12
25	8	16	9
26	8	15	8½
27	8	14½	9
28	10	14½	8
29	19	13½	11

The above table was compiled from five discs, loaned by Prof. Piersol, on which the temperature was recorded automatically. Each disc recorded a week's temperature. The number of hours during which the machine was in operation (by electricity) was estimated from the interval between the rise and fall of the temperature curve. There is an inconstant interval, after the machine has stopped, during which the temperature does not rise appreciably. This was estimated to be about one hour and has been deducted in making the above table.

TEMPERATURE RECORD OF THE BRINE AND VAULT AT THE ANATOMICAL LABORATORY OF THE JOHNS HOPKINS UNIVERSITY.

The machine was operated only part of the time, the object being to determine how well the insulation of the vault would hold the temperature below the freezing point.

TEMPERATURE IN DEGREES FAHRENHEIT.

Date.	Outside.		Brine.		Vault.		
1895.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	Duration of Run.
November 11....	59	69	..	..	29	25	8 hours
12....	59	62	..	..	29	25	2
13....	61	61	..	..	28	25	8
14....	62	73	11	0	26	21	8
15....	72	78	8	..	24	22	9
16....	71	78	6	5	24	20	4
17....	..	..	..	..	..	..	0
18....	63	69	14	5	27	23	6½
19....	71	68	10	6	25	21	7
20....	70	73	10	2	26	21	8

TEMPERATURE IN DEGREES FAHRENHEIT.

Date.	Outside.		Brine.		Vault.		
1895.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	Duration of Run.
November 21....	.	..	..	..	26	28	0 hours
22....	60	..	..	..	29	..	0
23....	62	..	..	..	31	..	0
24....	..	..	..	..	..	..	0
25....	62	73	22	10	32	25	8
26....	72	78	13	2	28	23	8
27....	70	76	8	2	25	22	8
28....	..	..	..	..	..	..	0
29....	60	69	13	4	26	22	8
30....	70	76	9	0	24	21	6
December 1....	..	..	..	..	..	..	0
2....	64	76	12	0	26	21	7
3....	62	68	8	2	24	20	8
4....	56	57	..	..	27	26	0
5....	57	64	..	..	28	29	0
6....	56	62	..	..	29	30	0
7....	58	64	..	..	30	31	0
8....	..	..	..	..	..	..	0
9....	60	66	..	..	32	32	0
10....	58	67	25	8	32	23	8
11....	59	70	11	1	26	27	8
12....	60	64	..	..	28	29	0
13....	59	62	..	..	29	30	0
14....	58	62	..	..	30	31	0
15....	..	..	..	..	..	..	0
16....	49	48	..	..	32	32	0
17....	68	78	20	8	32	24	8
18....	70	78	8	2	29	20	8
19....	70	69	..	..	29	29	0
20....	68	68	..	..	30	31	0
21....	67	69	..	..	32	32	0
22....	..	..	..	..	..	..	..
23....	60	74	20	6	32	23	8
24....	72	78	11	2	27	21	10
25....	..	..	..	..	..	..	..
26....	76	74	8	2	27	20	10
27....	72	78	..	..	28	29	0
28....	74	78	..	..	30	31	0
29....	..	..	..	..	..	..	0
30....	68	..	18	..	32	..	8
31....	66	..	7	..	25	..	8
1896.							
January 1....	..	..	..	..	..	..	0
2....	68	72	..	..	28	29	0
3....	68	74	..	..	29	30	0
4....	64	68	..	..	30	31	0
5....	..	..	..	..	..	..	0
6....	58	60	..	..	32	32	0
7....	60	62	..	..	32	32	0
8....	64	67	20	8	32	25	8½
9....	68	72	11	2	27	20	10
10....	66	68	..	..	28	29	0
11....	68	70	..	..	29	30	0
12....	..	..	..	..	..	..	0
13....	61	68	..	..	31	32	0
14....	68	74	18	3	32	22	10

ON THE DEVELOPMENT OF THE NUCLEI PONTIS DURING THE SECOND AND THIRD MONTHS OF EMBRYONIC LIFE.

BY MARGARET LONG.

(From the Anatomical Laboratory of Johns Hopkins University.)

This work was undertaken in the fall of 1899 at the suggestion of Doctor Barker, and has been carried out with his assistance. The specimens used are human embryos and were very kindly lent by Doctor Mall from his collection.[1]

[1] The numbers of the embryos correspond with their numbers in the embryological cabinet of the Anatomical Laboratory of the Johns Hopkins University.

The following embryos are described in the order of their probable age, as estimated by their length and by the development in the rhombencephalon. The arrangement of the cerebral nerves and the general appearance of the medulla oblongata agree with the His models and with the description given by His in "Die Entwicklung des menschlichen Rautenhirns"; a description of these is accordingly unneces-

sary. Each embryo has been studied in serial sections and from these sections a few, at different stages of development, have been selected as characteristic of the structure of the pons, its nuclei and fibres. To make the work complete it will be necessary to study more embryos at intermediate stages between the five given here, and others from the third month up to the adult pons.

Embryo No. LXXV is 30 mm. long and has been cut into serial sagittal sections. The nuclei, which I have designated as "B," "C," "D," "E" and "H" in the various sections, are masses of cells distributed through the ventral part of the mantle layer (Mantelschicht of His) at or near the level of the pontal flexure. The most medial of these nuclei extend to within 0.7 mm. of the middle line. An unstained fibre bundle can be seen on the surface of the rhombencephalon ventral to the mantle layer throughout its entire length.

Section No. 73 is 2.1 mm. to the left of the middle line (Fig. 1). Near the ventral surface on the cerebral side of the nervus trigeminus is a well defined cell-mass, "B." On the ventral surface opposite the nervus acusticus is a deeply stained cell-mass, "H," which (when followed in the series) is seen to extend lateralward and spinalward to the floor of the fourth ventricle at the junction of the latter with the telachorioidea. The section of the mantle layer presents longitudinal striations which have a slight ventral convexity. A few of these strands are more deeply stained than the rest between the level of the N. trigeminus and that of the N. acusticus. The dark ependymal epithelium and the unstained ventral fibre bundle are evident.

Section No. 91 is 1.2 mm. to the left of the middle line. On the ventral surface of the pons is a delicate shell or mass of cells, "H," continuous lateralward with "H" of the previous section. Between it and the mantle layer is the ventral fibre bundle. Dorsal from "A" is a cell-mass, "C," partially subdivided by a few colorless dorsoventral stripes; ventralward and cerebralward from "C" is another mass, "D," and still more cerebralward and dorsalward are two small deeply stained cellular masses, "E." The mantle layer of the medulla oblongata is deeply stained. It contains a diamond-shaped mass, "S," spinalward from "C," the longitudinal striations mentioned in the previous section, and an unstained dorsal fibre bundle (*DF*).

Section No. 96 is 1.05 mm. to the left of the middle line. "H" and "C" are still present. The ventral fibre bundle passes partly along the dorsal surface of "H" and partly between "C" and "E." Just cerebralward from the pontal flexure, close to the floor of the ventricle, is "M," an oval mass of cells with a clear unstained area behind at its spinal end, and measuring 0.8 mm. in transverse diameter. The appearance of the mantle layer is the same as before. In its dorsal and cerebral part is seen an unstained dorsal fibre bundle.

Embryo No. LXXXVI is 30 mm. long and has been cut into serial coronal sections. There is ventralward a definite mass which I have designated as the nucleus pontis ventralis; it is about 1 mm. long by 3 mm. wide. The raphe enters this nucleus in the middle line. Dorsal from its lateral part are several scattered masses which I have designated, tentatively, the nuclei pontis dorsales. The unstained ventral fibre bundle is dorsal from the nucleus pontis ventralis.

Section No. 175 is spinalward from the masses mentioned. On the ventral surface medialward from the nervus acusticus (*N.A*) is the cell-mass "H." Followed through the series this cell-mass extends spinalward, dorsalward and lateralward to the ependymal epithelium of the fourth ventricle; cerebralward, it is medial to the nervus trigeminus and continuous with the nucleus pontis. Taken in order from the raphe lateralward in the mantle layer are the nucleus olivaris superior (*S*) and the superior olivary complex (*S*), the ascending and descending parts of the root of the nervus facialis, the nucleus nervi facialis (*NNF*), and the corpus restiforme (*CR*). On the floor of the fourth ventricle are the nucleus nervi abducentis (*NNA*) and the nucleus N. vestibuli (radicis descendentis), (*HRVD*); further lateralward are the nuclei N. cochleæ, namely the nucleus N. cochleæ dorsalis (*NRCD*) and the nucleus N. cochleæ ventralis (*NRCV*). The unstained area is the ventral fibre bundle (*VF*).

Section No. 184 is 0.45 mm. cerebralward from the preceding section. In the mantle layer are seen in order the nucleus olivaris superior, (*S*), the nucleus nervi facialis (*NNF*), and parts of the ascending and descending limbs of the nervus facialis. "H" is on the ventral surface lateral from the nervus facialis. On the floor of the fourth ventricle is the nucleus N. vestibuli medialis et radicis descendentis (*NVV*).

Section No. 202 is 0.9 mm. cerebralward from section 184. The nucleus pontis ventralis reaches lateralward as far as the nervus trigeminus. In the middle line the raphe extends from the nucleus pontis to the ependymal epithelium. The nuclei pontis dorsales consist of several irregular masses, "A," "B," "C," and "E," and a more ventral and lateral mass, "D." These nuclei extend through the pons for a distance of 0.5 mm. in the cerebrospinal diameter. Between these ventral and dorsal nuclei is the unstained ventral fibre bundle. Lateral from the nervus trigeminus are the nucleus nervus trigeminus ascendens and an unstained area.

Embryo No. XLV is 28 mm. long, and has been cut in serial sections, which divide the pons in an oblique direction in the following way: Instead of corresponding to the transverse diameter of the pons the left side of each section is further spinalward than the right side of the same section. The ventrodorsal plane of the section is also oblique, so that in each section the left half of the dorsal surface is the more lateral, but in the right half of the pons the dorsal surface is more medial than the ventral. In other words, the first section removes a small portion of the pons about the cerebral ventral corner on the left side, and at the dorsal-spinal angle on the right side.

The nucleus pontis, as seen in this series, is on the surface of the rhombencephalon and follows the curve of the pontal flexure so that it is crescentic in shape, with a ventral convex surface and cerebral and spinal ends or horns. Consequently,

FIG. 1.—Section through the pons of embryo LXXV, 30 mm. long, × 15 diameters.

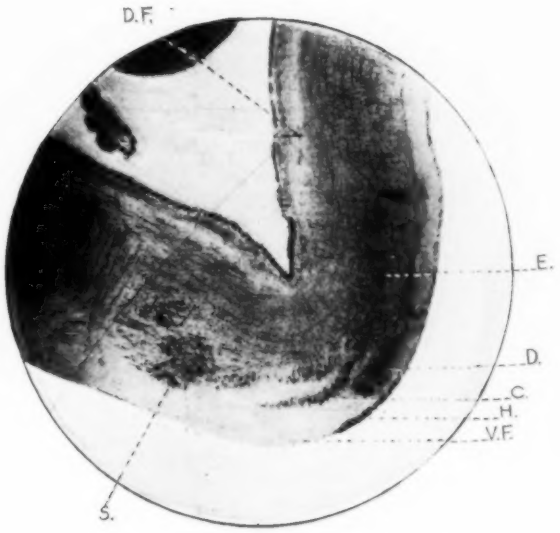


FIG. 2.—Section No. 91 of embryo LXXV, × 15 diameters.

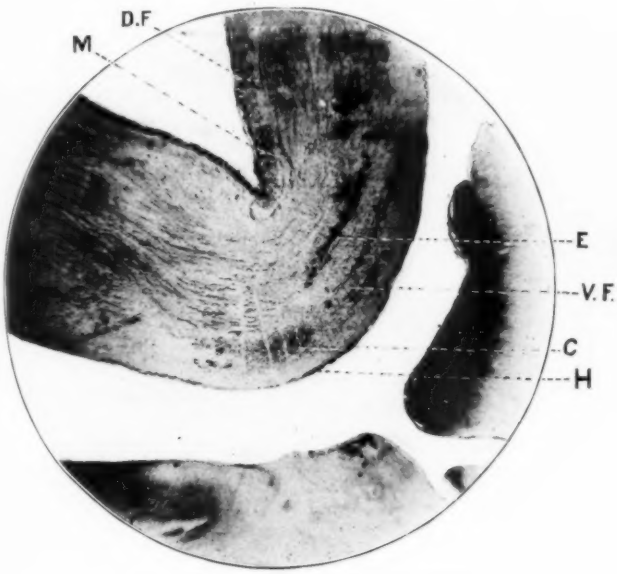


FIG. 3.—Section No. 96 of embryo LXXV.

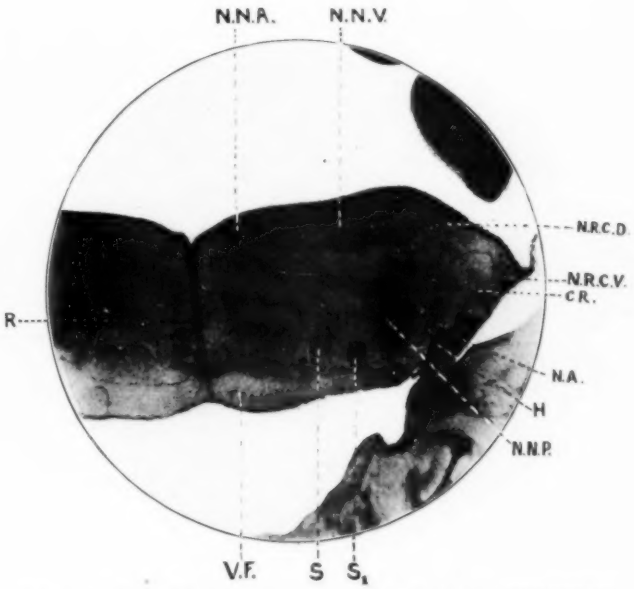


FIG. 4.—Section No. 175 through the brain of embryo LXXXVI, 30 mm. long, × 15 diameters.

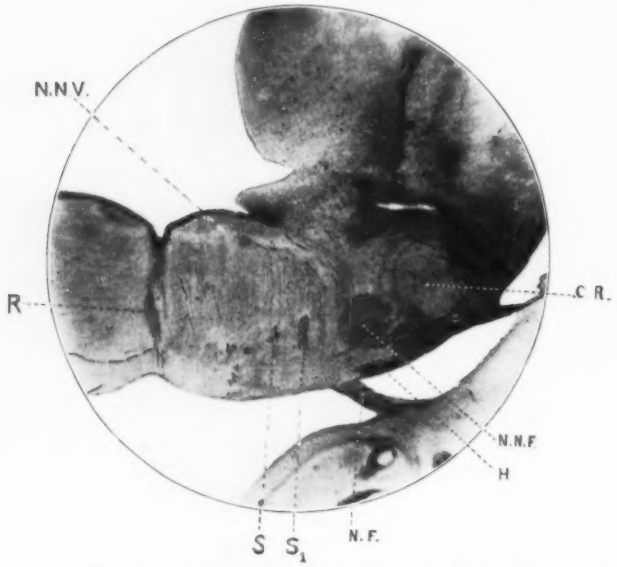


FIG. 5.—Section No. 184 through embryo LXXXVI.

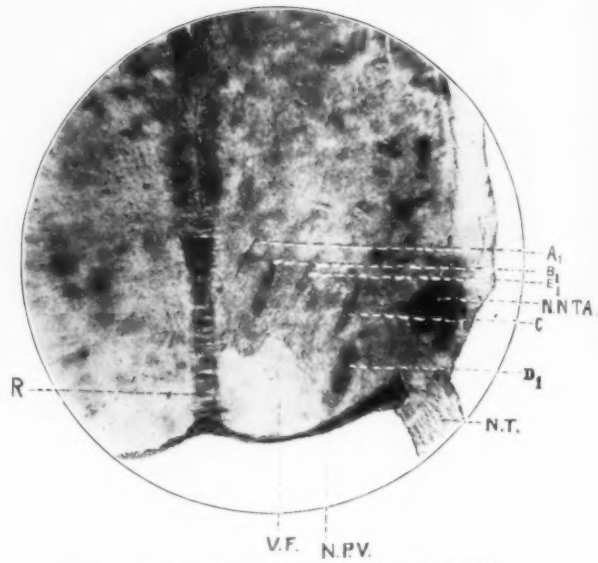


FIG. 6.—Section No. 202 through embryo LXXXVI

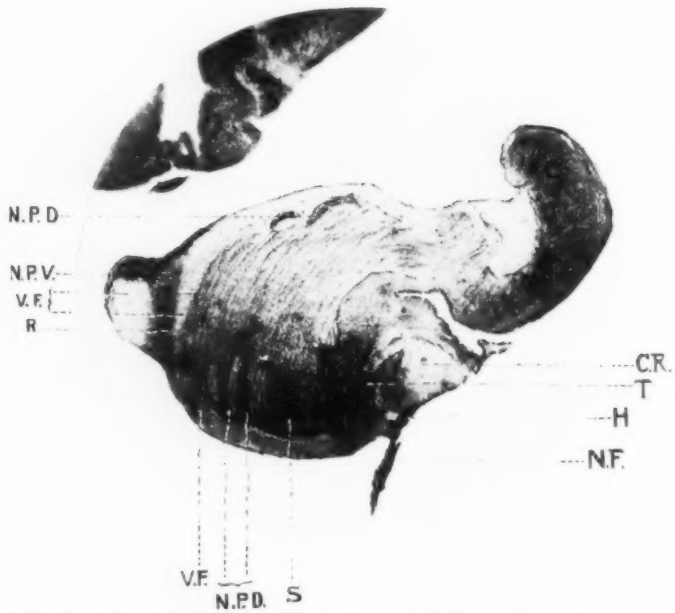


FIG. 7.—Section No. 136 through embryo XLV, × 15 diameters.

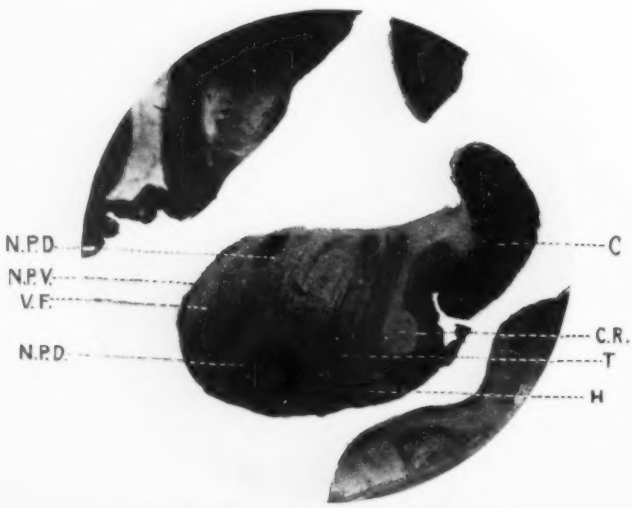


FIG. 8.—Section 142 through embryo XLV.

FIG. 9.—Section 145 through embryo XLV.

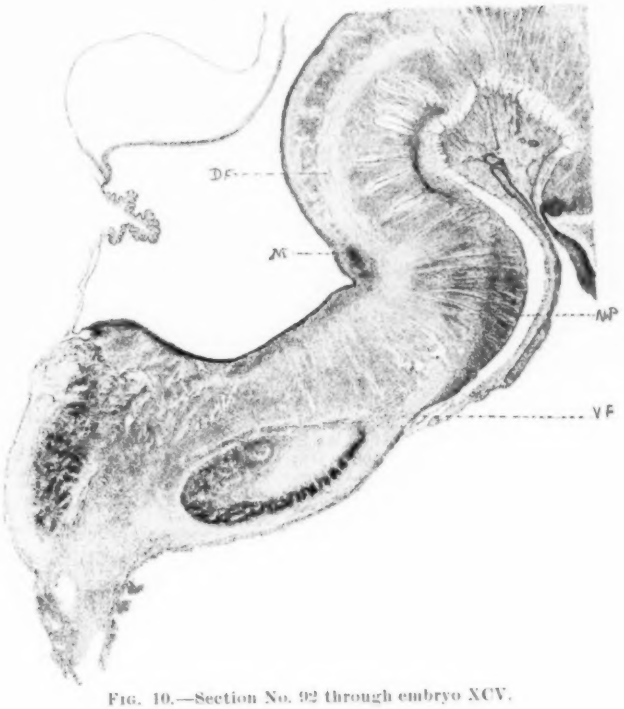


FIG. 10.—Section No. 92 through embryo XCV.

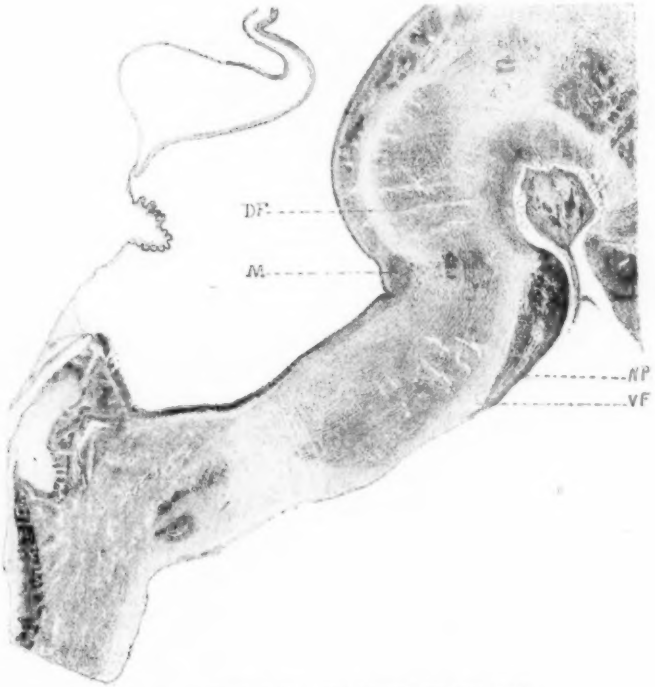


FIG. 11.—Section No. 100 through embryo XCV.

FIG. 12.—Section No. 106 through embryo XCV.

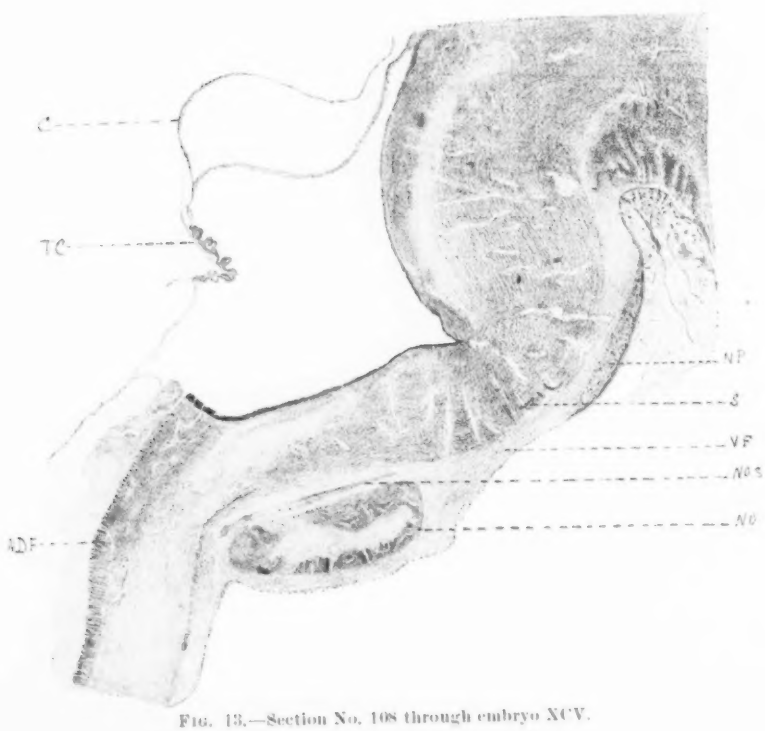


FIG. 13.—Section No. 108 through embryo XCV.

the following sections may have a ventrocerebral, a ventral, a ventrospinal and a dorsal edge.

The nucleus pontis ventralis is a solid mass of cells continuous with the raphe. The nucleus pontis dorsalis is divided into right and left halves not continuous in the middle line. The ventral fibre bundle passes between the ventral and dorsal nuclei except at their extreme lateral parts, where the cerebral ends of the two nuclei are united.

Section No. 136 is 0.05 mm. to the right of the middle line. On the right side the nucleus pontis ventralis is separated from the raphe by the ventral fibre bundle and nucleus extends across the middle line. On the left side the two ends of the nucleus pontis dorsalis are separated from the raphe by the ventral fibre bundle and mantle layer. On the ventrospinal surface at the level of the nervus facialis is a deeply stained mass of cells, "H." This mass is continuous opposite the nervus trigeminus with the nucleus pontis; spinalward, dorsalward and lateralward it extends to the ventricular epithelium of the medulla oblongata. In the medulla is a cell-mass, "T," on the medial side of the corpus restiforme, and reaching from the fourth ventricle to the ventrospinal surface. Between "T" and the nucleus pontis dorsalis is a small round mass, "S," a little more deeply stained than the rest of the mantle layer.

Section No. 142 is 2.5 mm. to the left of the middle line and shows only the left side of the pons. Between the nuclei pontis is the ventral fibre bundle. The nucleus pontis dorsalis is in the mantle layer; in its spinal end is a small unstained space. On the ventrospinal surface is the mass "H." Medial from the corpus restiforme is a round, deeply stained area "S." Near the fourth ventricle are several dark masses just like those in section 136.

Section No. 145 is 0.4 mm. to the left of the middle line. The nuclei pontis ventralis and dorsalis are continuous at their cerebral ends. Between them is the ventral fibre bundle. Opposite the radix N. cochleæ is "H," and median from it a cylindrical-shaped area. Between the cerebellum and the pons is an unstained area, the corpus restiforme.

Embryo No. XCV is 46 mm. long and cut into serial sagittal sections. The nucleus pontis is a solid mass of cells on the ventral surface of the pons, which has increased in size and measures 3 mm. in cerebrospinal, 4.6 mm. in transverse, and 0.5 mm. in ventrodorsal diameter. The ventral fibre bundle divides into two masses, the larger passes dorsal to the nucleus, the smaller through it.

Section No. 92 is 0.2 mm. to the left of the middle line. The nucleus pontis is a solid mass of cells. Dorsal from it is a dark wedge-shaped area; its ventral surface reaches as far as the nucleus pontis and extends 0.4 mm. beyond the middle line on each side, the dorsal surface is continuous with the ependymal epithelium in the middle line and for a distance of 0.3 mm. to the right. This area contains ventrodorsal markings, and small masses of cells staining more deeply than the rest of the tissue of the wedge between them. On the floor of the fourth ventricle just cerebral from the pontal flexure are two dark round cell-masses, "M," which extend through a few sections on either side of the middle line, but in the middle line are overlapped by the greatly thickened ependymal epithelium. On the ventral surface of the medulla oblongata is the ventral fibre bundle. Near the dorsal surface cerebral from the pontal flexure is the dorsal fibre bundle. The mantle layer contains the curved longitudinal striation, and in the isthmus is more deeply stained than in the medulla, and also contains blood-spaces. Next the ependymal epithelium the mantle layer of the medulla presents a uniform appearance, and in the isthmus it contains several darker masses of cells.

Section No. 100 is 0.6 mm. to the right of the middle line. The spinal portion of the nucleus pontis is divided into ventral and dorsal parts by a clear area, containing a few dark strands composed of cells. "M" is still present; between it and the nucleus pontis are several small cell-masses. The ventral fibre bundle is on the surface of the medulla and next the dorsal side of the nucleus pontis. The mantle layer contains the curved longitudinal striation and blood-spaces. Between the dorsal fibre bundle and the ependymal epithelium are numerous dark cell-masses.

Section No. 106 is 1 mm. right of the middle line. The nucleus pontis is more unevenly stained. Its cerebral end is divided into ventral and dorsal parts by an unstained area, which is continuous with the ventral fibre bundle. The fibre bundle extends the entire length of this section. It is now seen that this fibre bundle has an oblique direction through the cerebrolateral and spinomedial portion of the rhombencephalon. The appearance of the mantle layer is the same as in the preceding section; between the nucleus pontis and the nucleus olivaris a few of the curved striations are more deeply stained than the rest, "S."

Section No. 108 is 1.4 mm. to the left of the middle line. The nucleus pontis is a smaller mass, unevenly stained owing to the presence of large numbers of white spots (nerve-fibres). Dorsal from it is the ventral fibre bundle. The mantle layer appears as before but the mass "M" is not present. Between the nucleus pontis and the nucleus olivaris are a few small cell-masses, and several more are scattered throughout the mantle layer of the isthmus.

Embryo No. XCVI is 48 mm. long and cut into serial sagittal sections. The nucleus pontis has increased in the ventrodorsal diameter. The appearance of this specimen is almost identical with that of No. XCV, and is only of interest because it corroborates what was found there. So I have not thought it necessary to add illustrations. Just spinal from the nervus trigeminus the nucleus pontis is continuous with a mass of cells which reaches to the ependymal epithelium of the fourth ventricle. The ventral fibre bundle passes partly along the dorsal surface of the nucleus pontis and partly through it. Among the latter fibres are a few scattered strands of cells resembling more the appearance of the pons at later stage. The wedged-shaped area and the cell-mass appear as before.

The histological structure of these specimens is as follows: The ependymal epithelium contains large, dark, densely

packed, round and oval cells. The mantle layer in the earlier stages consists of round cells and a few oval cells. In embryo No. LXXV an unstained fibrous network is seen and the round cells are scattered through it, which in No. LXXXVI and No. XLV are more closely packed together. In the older specimens neuroblasts of the mantle layer point in various directions, a good many of them direct their axones ventralward, and many round cells are still seen. Most of the neuroblasts are now arranged in definite groups; between them is an unstained fibrous network which contains spongioblasts. Both the nucleus pontis and the mass "M" are composed of round cells in all the sections. The mass "H" consists of round cells, resembling in size and staining reaction those of the ependymal epithelium. The raphe appears in two specimens; it consists of fibres which interlace across the middle line, round cells, and in the frontal sections a few oval cells with their long axis transversely directed. In sagittal sections the raphe is not seen; its fibres, if present, would be cut in cross-sections.

Summary.

The main nucleus pontis is situated on the ventral surface of the rhombencephalon at the level of the pontal flexure. In the specimens the nuclei pontis are first seen on the surface and in the ventral part of the mantle layer of the lateral part of the pons Varolii. Ventral to all, in this early stage, except the mass of cells "H," is the ventral fibre bundle. In the second embryo the nucleus pontis ventralis extends across the middle line of the rhombencephalon and the nuclei pontis dorsales are separated from its lateral part by the ventral fibre bundle. The nuclei pontis dorsales next form two solid masses, reaching almost to the middle line. They are still separated by the ventral fibre bundle from the nucleus pontis ventralis, except at the extreme lateral ends, where they are continuous with each other. Next the nucleus pontis becomes a solid shell on the ventral surface cut by a small branch from the ventral fibre bundle. After the sixth month the pons consists mainly of fibres and scattered groups of cells which increase at the expense of the dorsal part of the nucleus, while a narrow ventral nucleus or cell-mass is left on the surface.

The neuroblasts of the pons are continuous with the epithelium of the floor of the fourth ventricle:

(1) By the cell-mass "H" at the lateral end of the nucleus pontis.

(2) By the round cells in the raphe.

(3) In the middle line by the neuroblast in the wedge which connects both the ependymal epithelium and the cell-mass "M" with the nucleus pontis.

THE ARCHITECTURE OF THE GALL-BLADDER.

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During the past few years the development of the surgery of the gall-bladder and ducts has increased the interest in their finer anatomy, and various investigations have been undertaken in order to add to our knowledge in regard to their structure. The lymphatics and finer blood-supply, however, do not seem to have had the same attention as the musculature and nerve supply; and so this paper deals more with this part of its structure and its histology than those which have been carefully considered in other papers.

The results mentioned here were obtained for the most part by the use of the gall-bladders of dogs and pigs. They were used because of their suitability and the ease with which they could be obtained. A limited number from cats and beeves were used also. The results thus obtained from fresh material were verified or refuted upon human gall-bladders as far as the limited supply and general bad condition of them allowed. Within a few hours after death the bile stains and macerates the tissues so that they are quite changed. The mucous membrane disappears entirely in from five to six hours after death; the nuclei and tissues under it refuse to stain, and it is impossible to obtain satisfactory results from any but the freshest material. For the histology small pieces hardened, distended and contracted in saturated corrosive sublimate solution yielded material that stained well and gave good pictures. For the connective-tissue elements the most striking picture was obtained by the use of Van Gieson's acid fuchsin and picric acid, but Weigert's elastic fibre stain furnished the most accurate and delicate picture. For the blood-vessels ordinary carmine gelatin mass and lamp-black or cinnabar gelatin mass were all that were necessary. For the lymphatics a saturated aqueous solution of Prussian-blue proved to be the best, notwithstanding a careful trial of a number of more complicated and presumably better masses.

The thickness of the wall of the gall-bladder varies according to its state of distention. In an adult human subject it is from $\frac{3}{4}$ mm. thick in a state of distention to 2 mm. in a state of contraction. The distended gall-bladder of a newborn infant is nearly $\frac{3}{4}$ mm. thick. In the pig it may be from $\frac{3}{4}$ to 3 mm. thick, and in a dog of medium size from $\frac{1}{2}$ mm. to $1\frac{1}{2}$ mm. thick. The wall of the gall-bladder is made up of the following coats: 1. mucous; 2. fibro-muscular; 3. subserous and on the free part covered by peritoneum; 4. serous. The relative thickness of these coats can be seen in Fig. 6, which shows the gall-bladder of the dog contracted. The relations are essentially the same in man as in the dog.

The mucous layer is thrown into a series of folds from ¼ to ½ mm. high in man. These folds of mucous membrane cover corresponding ridges of connective tissue of the fibro-muscular layer and contain an exceptionally rich capillary network. The irregular spaces surrounded by these folds are much larger at the fundus than at the duodenal end of the gall-bladder. In man the measurements in the distended gall-bladder are 3 mm. × 5 mm. in the fundus and 1 mm. × ½ mm. or smaller near the beginning of the cystic duct. In the crypts formed by the folds solitary lymph follicles are found. These are more numerous in the dog than in the pig, and in this regard there seems to be a great deal of individual variation. The mucous layer is composed of simple columnar epithelium, which rests upon an incomplete muscularis mucosa. In the dog these cells are from 25-42 μ thick. These cells seem to secrete a thick mucous material but no goblet cells are present. R. Virchow (1), in an article published in 1857, finds fine fat-drops in the ends of these cells of the gall-bladder and ducts during or just after the absorption of chyle. These droplets gradually became larger and worked toward the base of the cell. He thought this fat had been lost from the liver in the secretion of the bile and was again picked up by these cells. Nothing was seen in my preparations to suggest this. Granules were often seen in the outer end or near the base of the cells, but these gave no reactions for fat. Belonging also to the mucous layer were the tubular glands. These were beautifully shown in specimens stained in gold chloride. There are few of them in the dog, but in the pig, and especially in the ox, they are quite numerous.

The fibro-muscular coat is composed of smooth muscle fibres and interlacing bands of connective tissue. The direction and arrangement of these fibres has been very carefully studied by Hendrickson (2). He concluded that in the gall-bladder there are no definite layers and that the bundles of fibres interlace in all directions with the greatest number tending toward a transverse direction. According to Doyon (3), the muscle fibres arrange themselves in two methods in different animals: 1. A network with rather rounded meshes. This arrangement is found in the guinea-pig. This fact has been corroborated by Ranvier. 2. The muscle fibres are arranged into bundles which form a number of principal directions more or less plainly marked out. This is found in the dog and cat, and means about the same as the description of Hendrickson. My preparations and sections lead me to agree with Hendrickson, with the possible exception that near the fundus in the dog there is an outer and rather definite longitudinal layer. See Fig. 6. The part of this layer near the mucous membrane is composed almost entirely of connective tissue with only a few muscle fibres scattered through it, the part directly under the epithelium forming a mucosa which, however, shades off gradually and is not sharply separated from the underlying tissue. It is in this region that the thickest plexus of capillaries and intrinsic lymph channels exists. The solitary lymph follicles, to which reference has already been made, are found also here just under the mucous membrane. Toward the subserous layer, on the contrary, the muscle fibres are collected into well developed bundles (especially so in the pig and ox) and the connective tissue is correspondingly less. Elastic tissue occurs even here, however, varying in form from fine threads to coarse bands. It is especially abundant in the neighborhood of the blood-vessels. See Fig. 6. Unstriped muscle also exists in the larger gall-ducts, and at the point where the ductus communis joins the ductus pancreaticus it becomes modified into a sphincter. This has been found by Hendrickson in man, the dog and the rabbit, and also by Helly (4) in man, and Oddi (5) in man. The fibro-muscular layer contains the larger blood-vessels, which divide into branches and thus supply the other layers. See Figs. 2 and 6.

The subserous layer is composed of dense interwoven elastic tissue bands which contain comparatively few nuclei, and therefore few connective-tissue elements. These bands form an irregular mesh-work which is denser on the side toward the serous layer. This layer is poorly supplied with blood-vessels, although there is a well developed set of lymph channels which communicate with the large superficial vessels coming from the liver. By pulling the gall-bladder apart it is possible to divide it into two layers; the separation occurring at the junction of the subserous and fibro-muscular layers. By separating injected tissues in this manner a very pretty picture of the circulation in each part can be obtained distinct from the other.

The serous layer is present only on the part covered by peritoneum, *i. e.* the fundus, the inferior surface of the gall-bladder and the outer surface of the gall-ducts. It is composed of simple flat endothelial cells from 4-6 μ thick and adds but little strength to the organ. The larger lymphatic vessels from the liver and deeper layers of the gall-bladder run between it and the subserous layer.

Brewer (6) has described in a very careful manner the way the cystic artery reaches the gall-bladder in man and the variations one would find ordinarily. He found that in 50 subjects only 3 corresponded to the type described in text-books of anatomy. It is possible to judge from this of the great amount of variation existing in its blood-supply. The largest artery after it has reached the gall-bladder is usually found, however, on its inferior surface and on the side toward the middle line of the body. There also may be a smaller branch on the side away from the middle line. This is covered at first by peritoneum and then penetrates the outer part of the fibro-muscular layer and gives off the branches which supply the viscus. Most of the larger vessels are in the fibro-muscular layer near the dividing line between it and the subserous layer. See Fig. 6. If the needle of a hypodermic syringe be introduced into one of the smaller arteries and the mucous surface be watched while the fluid is slowly injected the arterioles and capillaries can be seen to be filled in areas about 2½ mm. in diameter at a time from a single centrally placed artery. The capillaries under the mucous membrane are very numerous and in the folds the capillary network is especially thick. See Fig. 2. The blood from

these is collected into the veins and returned to the larger and deeper lying ones accompanying the arteries.

The subserous layer has a comparatively poor blood-supply. The arteries are small and the capillaries widely separated. Some of the capillaries run out between this layer and the serous layer, and thus provide for the nourishment of the peritoneal covering. Some veins of considerable size are also found in this layer. On the surface of the gall-bladder in contact with the liver the veins communicate with the branches of the portal vein and the arteries in part come from the hepatic artery.

The large lymphatic vessels running over the gall-bladder bring lymph from the liver and the coats of the gall-bladder. They follow the inner side of the cystic duct and end in mesenteric lymph glands in the dog. In the pig and in man we have either one or two systems of the large lymph vessels. In almost all cases both are represented but the territory may not be equally large and there is wide variation in their method of distribution. In cross-section these vessels are always flattened although the degree of flattening varies with the completeness of the injection. Sappey (7) figures a mass of them running over the gall-bladder in a manner somewhat resembling Fig. 4, but he only mentions the fact that they bring in the lymph from the liver and deeper layers of the gall-bladder. In my preparations they run down eventually on the inner side of the gall-bladder but there is usually a large vessel coming from the same side, but with the exception of one specimen figured in Plate 2, Fig. 4, which was believed to be pathological, are not as numerous as shown by Sappey.

In the subserous layer there is a network of lymph channels which empty into these larger vessels. See Fig. 7. This network is very irregular and the lymph channels vary markedly in size and shape. The picture of these lymphatics which seemed most normal was obtained by injecting carmine gelatin into the portal vein at a pressure of 80 mm. of mercury for fifteen minutes. This injects the lymphatics of the liver and in turn the larger ones over the gall-bladder, and finally these in the subserous coat in a more or less complete manner, but without any tearing or stretching of the vessels. In Fig. 2 they are represented as though the greater part lie simply on top of the subserous layer, while, as a matter of fact, they are scattered through it rather evenly.

The submucous sets of lymphatics are in the connective tissue just under the mucous membrane. However, they rarely run up into the connective-tissue folds but are at their lowest part or more frequently just at their base. The network is almost entirely absent in the denser muscular part. These were best seen by injecting aqueous Prussian-blue slowly under the mucous membrane and the injected portion was afterwards fixed and studied. In some cleared specimens the lymphatic vessels could be seen running up and joining the more superficial lymphatics of the subserous layer or directly one of the large superficial vessels as shown in Fig. 1. The lymphatic tissue belonging to this layer has already been described.

The nerve supply of the gall-bladder has been studied by Dogiel (8) and Huber (9) within recent years. The nerve supply is derived from two sources, viz., 1. the sympathetic system of ganglia and fibres connecting them, and 2. medullated fibres accompanying the large arteries. In regard to the distribution of the sympathetic fibres Huber suggests from the condition prevailing in other viscera that they supply the blood-vessels and smooth muscle of the coat. Doyon thinks these are unable to act without receiving stimuli indirectly from the great splanchnic nerve. Dogiel has figured in a beautiful manner the kinds of cells found in the sympathetic ganglia and concludes that all the varieties found in the walls of the intestines occur here also. Quite a number of medullated fibres are also found near the large arteries. Both Huber and Dogiel have noted them. The former suggests that they are sensory fibres and are distributed to the mucous membrane. Their termination, however, has not yet been settled by direct observation.

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Description of Plates XXV-XXVI.

Fig. 1.—The gall-bladder of a pig; natural size. The lymphatics were injected by placing the needle just under the peritoneal covering of the liver near the edge of the gall-bladder at (*N*). The blurred mass in the centre represents the injection mass showing through and the

FIG. 1.—Gall-bladder of pig.

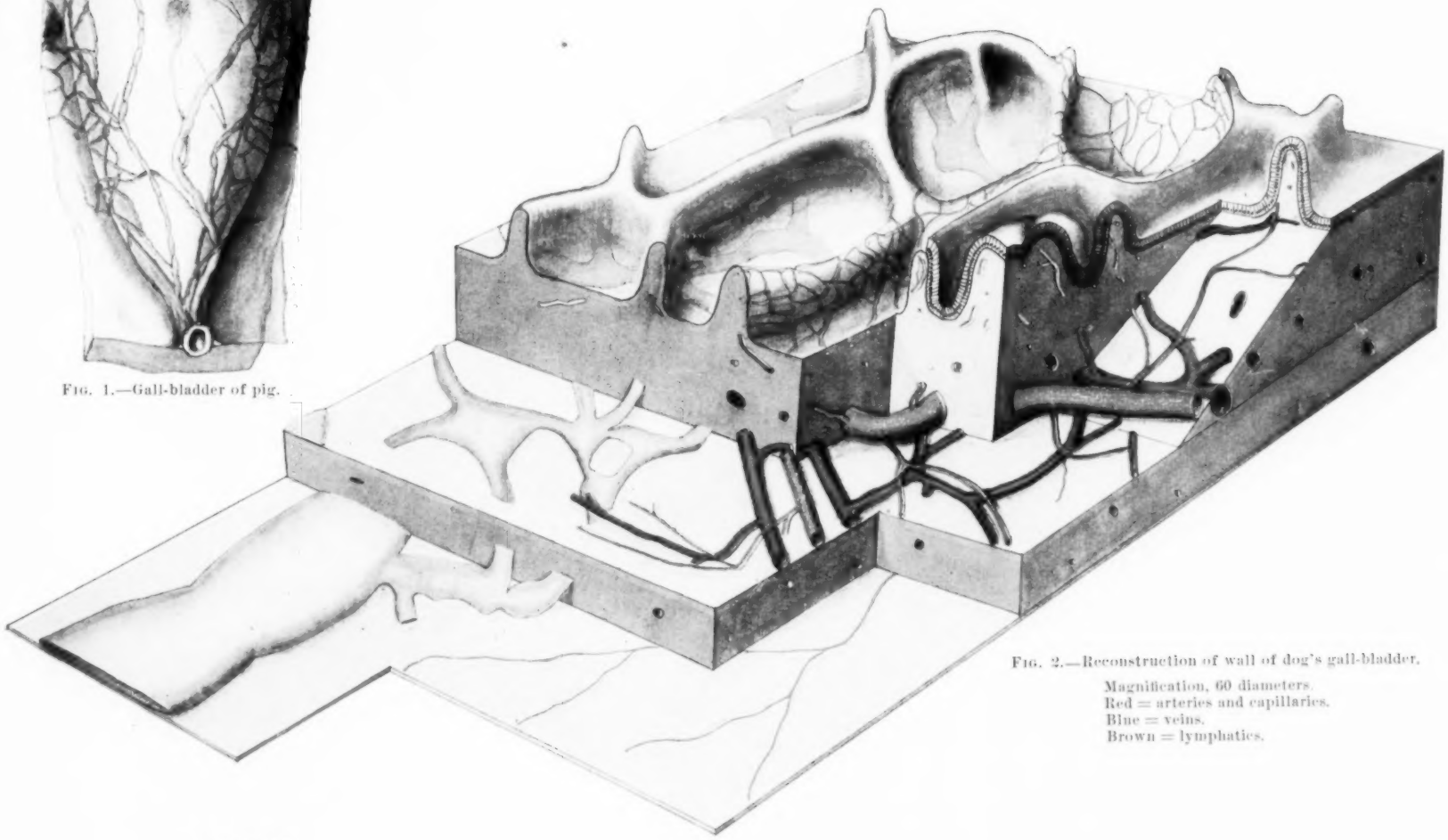

FIG. 2.—Reconstruction of wall of dog's gall-bladder.

Magnification, 60 diameters.
Red = arteries and capillaries.
Blue = veins.
Brown = lymphatics.

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FIG. 3.

FIG. 4.

FIG. 5.

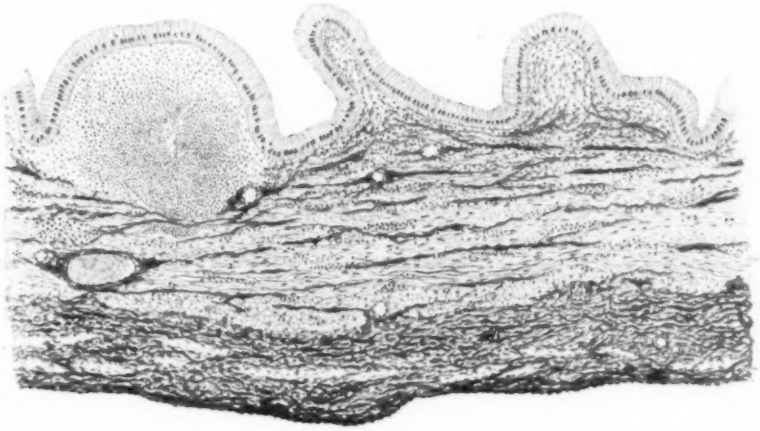

FIG. 6.

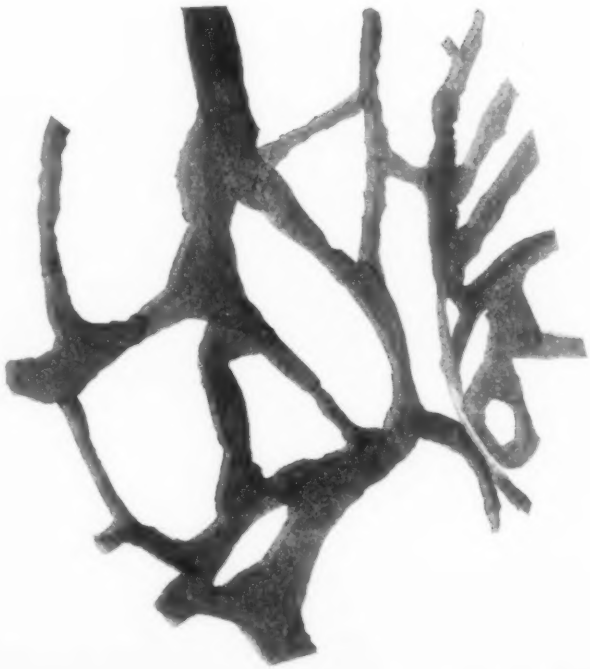

FIG. 7.

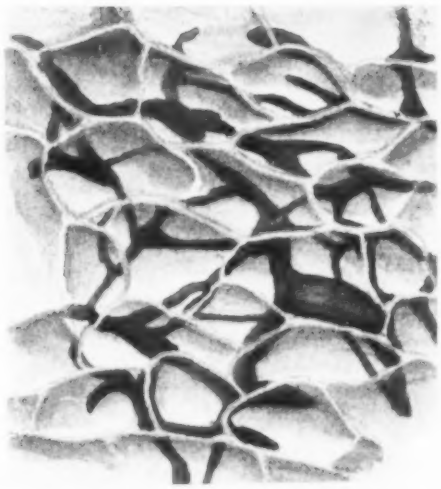

FIG. 8.

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lymphatic vessel coming up from the deeper layer to join the large superficial one. *N* = Needle of syringe.

FIG. 2.—Reconstruction of the wall of the partially contracted gall-bladder of a dog, magnified 60 times, showing the blood-vessels on the right and the lymphatic vessels on the left. Lymph follicles are shown on the right as two rounded eminences just under the epithelium. The vena comites shown is quite characteristic for the larger arteries. The large lymphatic vessel is shown partially collapsed.

FIG. 3.—Gall-bladder of adult man, showing superficial lymphatics. ½ natural size.

FIG. 4.—Gall-bladder of man 19 years old, dead of chronic nephritis, showing the large superficial lymphatics. This gall-bladder gave evidence of having been through an inflammatory process, and so the lymphatics are probably abnormally numerous.

FIG. 5.—Gall-bladder of dog, showing the superficial lymphatic vessels. Natural size.

FIG. 6.—Section through the contracted gall-bladder of a dog, magnified 80 times, showing the arrangement into coats and the relations of the blood-vessels.

FIG. 7.—The lymphatics of the subserous layer of a dog. (Camera drawing.)

FIG. 8.—The lymphatics of the fibro-muscular layer of a dog, showing their relation to the folds on its surface. These folds are represented narrower and less complicated than in the specimen in order not to hide the lymphatics. (Outlines made with the aid of a camera.)

REMARKABLE CASES OF HEREDITARY ANCHYLOSES, OR ABSENCE OF VARIOUS PHALANGEAL JOINTS, WITH DEFECTS OF THE LITTLE AND RING FINGERS.

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Accounts of diverse abnormalities of the arms, forearms, hands, and feet, are to be found in literature from the remotest medical history, and not a few books and monographs on these various defects have appeared from time to time. Most of these reports comprise instances of polydactylism of various degrees; abnormal shapes of the metacarpal and phalangeal bones; absence of the phalanges and carpal bones; increase in the number of the phalanges; absence of fingers; absence of the bones in the arm and forearm; abnormal shapes and lengths of the radius and ulna; lateral union of the phalanges; union of the fingers by the soft parts, etc.

Two cases have recently come to my knowledge which have sufficient bearing on the ones herein reported to warrant a short synopsis of them in this paper.

The first was that of a child in which there was a lateral fusion of the first and second metacarpal bones of both feet. This was not supposed to be hereditary until the grandmother, upon examining her own foot, to show where the defect had occurred in the child, found her own bones in exactly the same condition. Although she was seventy years old, she had never previously noticed it.

The second case was that of a young girl whom I examined. There was a partial stiffening in the metacarpo-phalangeal articulation of the thumb; this was ligamentous, and not bony, and permitted a certain amount of motion, probably about one-half that of normal. This defect had occurred in one of her brothers, one uncle, her father and her grandfather. All of them were afflicted in the same joint, and had about the same amount of motion.

The cases which I herewith report show either a complete bony anchylosis or an absence of various joints between the phalanges, together with an absence of one or more bones of the little and ring fingers. As will be seen in the family tree, it has occurred in five generations. I have examined the cases so far as possible, and have made Roentgen photographs from four of them, thus representing two generations.

Thomas B. applied to the dispensary of the Johns Hopkins Hospital for the treatment of leg ulcer. He was fifty-two years of age, well nourished and apparently well developed and healthy. On examination of his hands I found the thumb and index finger normal; in the ring and middle fingers nothing could be seen on inspection in the extended hand, contrary to the usual type, but on palpation there was found an entire bony anchylosis of the second metacarpal joints of above fingers; the bony enlargements corresponding to the heads of the bones were present, and in the middle finger a distinct sulcus could be felt on the thumb side; other than this the enlargement was regular and smooth. The terminal joints were negative. The little finger presented only two phalanges, there being, however, near the end of the first phalanx, a slight enlargement which possibly corresponded to a joint. The thumb was 7 cm. in length; first phalanx, 4 cm.; and second phalanx, 3 cm. The index finger, 8½ cm.; first phalanx, 3¼ cm.; second, 3 cm.; third, 2¼ cm. Middle finger, 9¼ cm.; first and second together, 7½ cm.; third, 1⅞ cm. The first from basal joint to middle of enlargement, 4 cm.; the second, from middle of enlargement to distal joint, 3½ cm. Ring finger, 9 cm.; first and second phalanges, 6⅞ cm.; third, 2¼ cm. Little finger, 6 cm.; first phalanx, 3½ cm.; second, 2½ cm. The left hand presented nearly the same appearance, and on careful palpation and measurement the only difference found was that in the little finger, first phalanx, there was a slight bowing, making a palmar concavity toward the end. This was due, according to the statement of the patient, to an old fracture. The enlargement at this site, as is shown in Roentgen Photograph No. 1, is very much greater than in the other hand, and suggests that it had probably been caused by trauma; in the other finger the enlargement can be seen, but to a much less degree, thus making it doubtful whether there is an obliterated joint, or the absence of the middle phalanx. The metacarpals were of normal length and their articulations were negative. The carpus was negative. The feet presented nothing abnormal, except a slight giving way of the arch. The other parts of

the osseous system were well developed and did not differ from the usual types. The patient stated that the deformity gave him very little inconvenience, and did not interfere with his work. Both the above hands are shown in Roentgen Photograph No. 1.

On being questioned in regard to his family history, he said that his father, grandfather and great-grandfather were similarly affected. The middle joints of all his father's fingers were stiff; the defect in the grandfather and great-grandfather was known to have existed, but the exact nature could not be determined. He had three uncles and one aunt; two of the uncles he thought were affected, but was not certain; the other uncle and aunt were free. In his immediate family there were four brothers and one sister. One brother and the sister had negative hands; the other three brothers presented the family trait. He had four children, all of whom were free. His younger brother had had three children, two dead and one living, none of whom were affected. His elder brother had eleven children; four of them, two boys and two girls, had the defect. I have visited and examined the two brothers and their families, and I give in the following a report of said examination.

Henry B., the younger brother of the above described, is a gardener, 48 years old; a strong, well built, healthy man; five feet eight inches in height and weighs 148 pounds. Both hands are affected. Right thumb, negative; length, 7 cm.; first phalanx, 4 cm.; second phalanx, 3 cm. Index finger, length, 6¾ cm.; first and second, 5 cm.; third, 1¾ cm.; the first joint is normal, second is stiff, distinct bony enlargement at site of joint, slight sulcus on thumb side. Middle finger, 9½ cm.; first and second phalanges, 7½ cm.; third, 2 cm.; first from basal joint to middle of enlargement, 4¼ cm.; first joint is negative, the second is stiff with rounded, smooth, bony enlargement; no sulci. Ring finger, 8½ cm.; first and second, 6½ cm.; third, 2 cm.; first joint is negative, second anchylosed, bony enlargement not so marked. Little finger, 5½ cm.; first and second, 3¾ cm.; third, 1¾ cm.; the first joint completely stiff, second negative, metacarpal bones and carpus negative. Other hand presented same appearance and nearly the same measurement. Feet and remainder of bones in the body did not differ from normal.

William B., elder brother, very strong, hale, robust man, 58 years of age, 5 feet 11 inches in height, weighed 172 pounds. Both hands affected, as shown in Roentgen Photograph No. 2. Middle joint, ring and middle finger and both joints in little finger stiff. Thumb and index finger normal, remainder show absence of middle joints. Length of thumb, 7 cm.; first phalanx, 4½ cm.; second phalanx, 2½ cm. Index, 8 cm.; first phalanx, 3½ cm.; second, 3 cm.; and third, 1½ cm. Joints all negative. Middle finger, 9½ cm.; first and second phalanges, 7½ cm.; third, 2 cm. The first joint completely anchylosed, distinct thickening at joint site, with small depression. Ring finger, 9 cm.; first and second, 7 cm.; third, 2 cm.; first joint site presents usual bony enlargement, but no joint was present; second joint negative. Little finger, 5½ cm.; slight palmar concavity, complete anchylosis of both joints; 1½ cm. from the end there is a slight enlargement with furrow in middle at joint site, but no motion; the first joint is also completely immobile. The metacarpals are normal in length, size and articulation; the carpus is negative. The left hand does not differ in essential characteristics from the one described. The feet presented no abnormality.

The patient stated that he had worked at the same bench with two men for fifteen years, and they had never noticed the defect. He had eleven children in his family, four of whom were affected; the others had perfect hands.

I have seen most of the children of the above described, and the following is the condition of the four who are affected.

Sallie B., aged seventeen, rather poorly developed, tall and slim, height five feet six inches, weight 115 pounds, both hands affected, as shown in Roentgen Photograph No. 3. Thumb and index, free; right hand, thumb, 6 cm.; first phalanx, 3½ cm.; second phalanx, 2½ cm.; joint normal. Index finger, 7 cm.; first phalanx, 3 cm.; second, 2¼ cm.; third, 1¾ cm.; both joints negative. Middle finger, 8½ cm.; first and second, 6½ cm.; third, 2 cm.; complete anchylosis first joint, second joint is negative. Ring finger is represented only by the first phalanx, which is 4 cm. in length. The distal end is slightly enlarged, and tapers towards middle finger. The little finger is represented also by only first phalanx, 3½ cm. in length. It presents same shape of enlargement at distal end as ring finger. The left hand is the same as right, except that the middle joint of the index finger is anchylosed. In these hands, notably in the left one, there is a distinct crowding together of the metacarpals, being most marked in the fifth, which, as shown in the photograph, decidedly overlaps the fourth. The carpi are negative; the remainder of bones apparently normal. The feet were not examined, but according to the statement of the patient they presented no abnormalities.

Carrie B., aged fifteen, rather strong and robust, weight one hundred and seventeen, five feet four inches in height. I was unable to procure a photograph of this hand on account of the unwillingness of the patient. Both hands are affected, and very similar to those of her sister, as above described. Right hand, thumb and index finger, normal. Ring and little fingers of both hands, as in the case of her sister, present only one phalanx, that of the ring finger is 4 cm. in length, and that of the little, 3 cm.; the distal ends are slightly enlarged, and according to palpation are like her sister's. In the other hand the index finger is anchylosed at the middle joint, and the middle finger presents a striking peculiarity in that the anchylosis is in the second joint, the first being free.

Henry B., a picture of whose hand I was unable to obtain, but upon examination found the following conditions:

Not very robust, tall and slim, age fifteen; height five feet six inches, weight one hundred and twenty pounds, both hands affected. Index and thumb in both negative, remainder affected. Thumb, right, 5½ cm.; first phalanx, 3 cm.; second phalanx, 2½ cm.; joint negative. Index, 7½ cm.; first phalanx, 3 cm.; second, 2½ cm.; third, 2 cm.; phalanges normal in size, and joints negative. Middle finger, 8½ cm.; first and second

phalanges, 6¼ cm.; third, 2¼ cm.; first joint is stiff with distinct bony enlargement, and slight depression between heads of bones; second joint is negative. Ring finger, 8 cm.; first and second, 6 cm.; third, 2 cm.; first joint is anchylosed, second is negative. Little finger, 5½ cm.; first phalanx, 4 cm.; middle is absent; the third, 1½ cm. There seems to be an entire absence of the second phalanx; the first is normal and presents no enlargement which might correspond to a joint. The left hand differs in one particular from the above described, in that the terminal phalanx of the little finger is turned inward toward the ring finger, and forms an angle of 135 degrees with the second phalanx. The metacarpals and carpi are negative. The remainder of the bones present no defects.

George B., aged seventeen, height five feet six inches, weight one hundred and fifteen pounds, rather poorly developed, slightly anemic. Both hands shown in Roentgen Photograph No. 4. Right hand, thumb, 6 cm.; first phalanx, 3¾ cm.; second, 2¼ cm., joint, normal. Index finger, 7 cm.; first and second, 4¾ cm.; third, 2¼ cm.; first joint site shows normal enlargement, but is stiff; second is negative. Middle finger, 8 cm.; first and second, 6 cm.; third, 2 cm.; first joint completely anchylosed; second, negative. Ring finger, 7½ cm.; first and second, 5½ cm.; third, 2 cm.; first joint stiff; second, negative. Very slight enlargement at first joint site. Little finger, 5 cm.; first, 3¼ cm.; second, absent; third, 1¾ cm. Joint is negative; first phalanx is normal in length and shape, there being no enlargement nor anything to suggest an anchylosed joint. Metacarpals and carpi negative. The other hand presented the same appearance. The remainder of the body negative.

In perusing the literature bearing on these subjects, I have found only a few similar cases reported, none of them being so marked as mine, and only one was hereditary.

Klausner, in a rather exhaustive monograph on various deformities of the arm and hand, reports a case in which the anchylosis was present in the second phalangeal joint of the index finger; the hand was very much deformed otherwise, and the fingers partly webbed. There was no hereditary history, nor were any other members of the family so affected.

Wolf, very recently, has put on record an anchylosis of the second phalangeal joint of the little finger. In this case the middle phalanx was very much shortened and was joined to the first by a bony union at an angle of about 145 degrees. The terminal phalanx was apparently normal. This anchylosis had occurred in four generations, and was present in eight instances. Some of them were inherited from the father and others from the mother. The same joint of the same finger was affected in every case; the remainder of the hand was normal; there is no record of any other defects in the body; the condition of the pectoral muscles is not mentioned. The fingers in the cases of both Klausner and Wolf are shown by Roentgen photographs.

R. Stintzing reports a case of a very much deformed hand in which there was an almost complete anchylosis in the second joint and partial in the first. In this case the fingers were webbed; a diminution in the length of several of the middle phalanges and a defect in the right pectoralis major muscle.

J. Sklovowski relates an instance of a defect of the sternum, pectoralis major and minor muscles, and a portion of the back muscles, together with an absence of the second phalanx in the second and third fingers; a shortening of the other phalanges, and a limitation of movement in nearly all of the phalangeal joints, with a complete anchylosis of both joints in the fourth finger.

Hoffman describes a deformity occurring in a man 48 years of age, in which there was a stiffening in one or more phalangeal joints, and a shortening of the middle phalanx of the middle finger. In the index finger the middle phalanx was small and completely fused with the third phalanx. There was also webbing of the fingers, associated with muscular defects in the chest and back muscles.

Fuerst gives an accurate account of a hand which was examined after death by a very careful dissection. In this hand there was great shortening and malformation of the middle phalanx of the middle and ring fingers. There was no anchylosis in any. In all of the above cases, with the exception of the last, the observations have been made on the living subject, and usually by palpation alone.

With the exception of the two girls in the present generation of the cases which I herewith report, none of the females have heretofore been affected, and in them appeared the only instances in which the terminal phalanges were absent. There is another striking difference in one of them, as is shown in the Roentgen Photograph No. 2, in the partial overlapping of the fifth metacarpal bone, which suggests the possibility that continued transmission might produce a fusion, or an absence of one of these bones.

From the above it will be seen that the defects have existed in five generations, and have been confined entirely to the hands, the remaining osseous system presenting no peculiarities. Except in the present generation the hands have been otherwise normal. The first departure from this was in the case of the boy, Roentgen Photograph No. 4, where there is an absence of the middle phalanx of the little finger; while in both of the girls, as is shown in one by the Roentgen Photograph No. 3, the end and the middle phalanges of the middle and ring fingers are absent. There is also a partial obliteration of the distal enlargement of the remaining phalanges.

By a study of the photographs, one can see that there is undoubtedly a bony union and not a fibrous anchylosis in the joint sites. The enlargements corresponding to the heads of the bones are plainly to be seen and felt, but the joints are absolutely unformed. In a number, small sulci could be palpated, corresponding to the normal depression between the heads of the bones. The photographs also show that there is a certain porosity at the joint sites, which seems to be more than normal.

The question arises whether these are cases of entire absence of the joints, or of early anchylosis. The two phalanges are about the normal length, and there is a distinct enlarge-

ment corresponding to the metacarpal heads, with small sulci between some of them, but other than this there is no evidence whatever of an attempted joint formation. In view of the fact of a complete bony union, it appears best to consider them as cases of an absence of the joint rather than of an anchylosis. It has been suggested that probably the anchylosis may have occurred after birth as the result of some disease; but according to the statements of the mothers of these various children, it was a congenital defect. A careful examination of the other bones failed to show any abnormal conditions or diseases, and the history of lues was not present.

The examination of the arm shows a fairly good muscular development, and so far as could be made out there was no atrophy of the flexor sublimis digitorum. The muscles of the hand were also well developed and the thenar and the hypothenar eminences were apparently normal. There was an exception to this in the hand of the girls, where there was found a rather poor development of the hand muscles, which was most notably marked at the hypothenar eminence.

The palmar folds in the hand were normal, but in the skin over the anchylosed joints they had become nearly smoothed out; the two normal creasings being scarcely discernible.

The epiphyses were all joined; which was unfortunate as otherwise some light might have been thrown on the bony development.

In nearly all of the reported cases there have been defects in the back and breast muscles; the most striking examples of which were found in the pectoral region. The cases which I herewith report presented no such abnormality, and showed upon examination a completely developed condition of the muscles of the arm, shoulder and back. In all the instances the feet were negative.

These cases are in striking contrast to the generally accepted opinion that deformities of the hands and feet are transmitted by the mother, for in each of those in this series it came through the father, the mothers having all been normal. It is most interesting to note that in each generation only one male member has transmitted the deformity to his offspring.

The occupations of the individuals were very little interfered with; the only inability complained of was that of being unable to grasp small articles with the whole hand. The deformity, except in the cases of the two girls, was not at all striking, and unless one carefully inspected the hands it would be overlooked, and even in shaking hands it was not noticeable.

Shortening of the Phalanges.

In my cases, as well as in most of the above-reported ones, there has been a decided shortening of one or more of the phalanges. It has been in nearly every instance most strikingly observed in the middle phalanx with a certain predilection for the little finger.

In discussing such cases, Fuerst states that in nearly all of these defects the shortening is seen in the middle phalanx, and he ascribes it to the fact that in embryologic development the middle phalanx is the last to become bony. This occurs when the embryo is about 8 centimeters in length, and he thinks that at this period the deformity commences. From observations of his case, and a study of certain others, he concludes that the shortening and anchylosis are stages in fusion of the first and second bones. The shortening represents the first stage; the anchylosis the second stage, and the whole phalanx the third stage.

This theory does not seem to be based upon sufficient observation, nor is there enough evidence in the studied cases to justify any such assumption.

In my cases, as is shown in the photographs, there is no shortening at all in the phalanges of the second and third fingers, although a complete anchylosis exists; this would stand directly against the theory which Fuerst has advanced. In the little finger, however, there is some evidence for the hypothesis, for in the second generation there is present a diminution in the phalanx, then an anchylosis, and finally, in the case of the boy, the joint has entirely disappeared, and there remain only two normal phalanges.

A very distinct and decidedly unique type, so far as the above-mentioned cases are concerned, is to be seen in the hand of the girl; for in this case the end and middle phalanges have entirely disappeared, and have left the first phalanx only partially developed. The diminution and absence of the end phalanx were not noted in the other reported cases, and can not be explained on the ground of the late bony development.

The little finger first shows a beginning defect, and in the case of Thomas B., Roentgen Photograph No. 1, left hand, the first phalanx is long, somewhat curved, and presents a slight enlargement which probably corresponds to a joint site. The middle phalanx then will be represented by a small bone about 1½ cm. in length. In the case of the nephew there are certainly only two phalanges; and in each of the girls only one is present, and the defect has extended to the ring finger.

Thanks are due to Dr. Finney for permission to report these cases. I am also indebted to Professor W. A. S. Hammel for the care which he gave to the preparation of the photographs.

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FIG. 1.

FIG. 2.

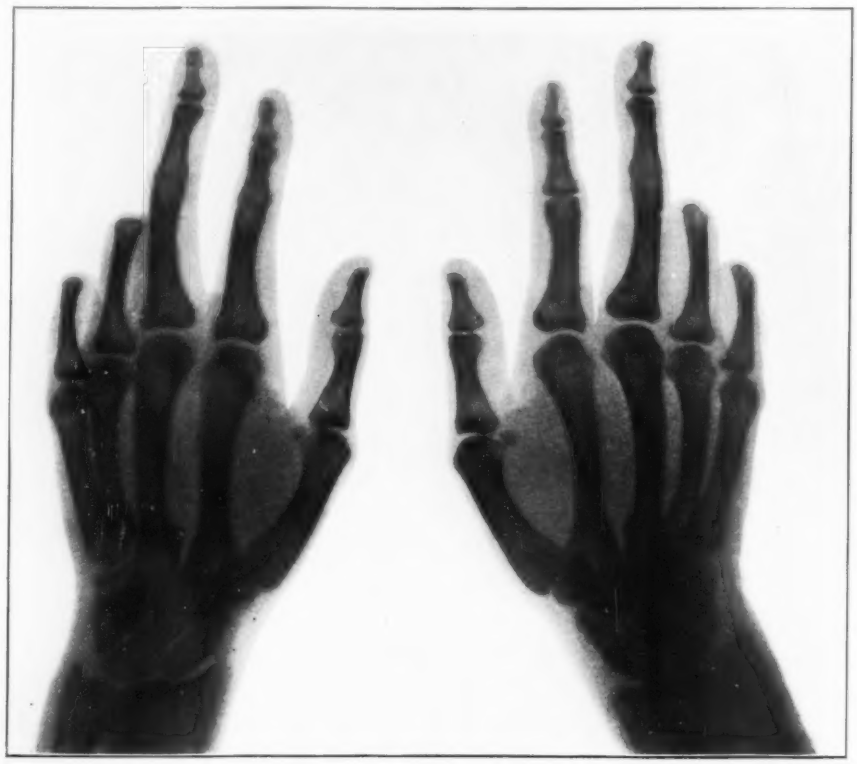


FIG. 3.

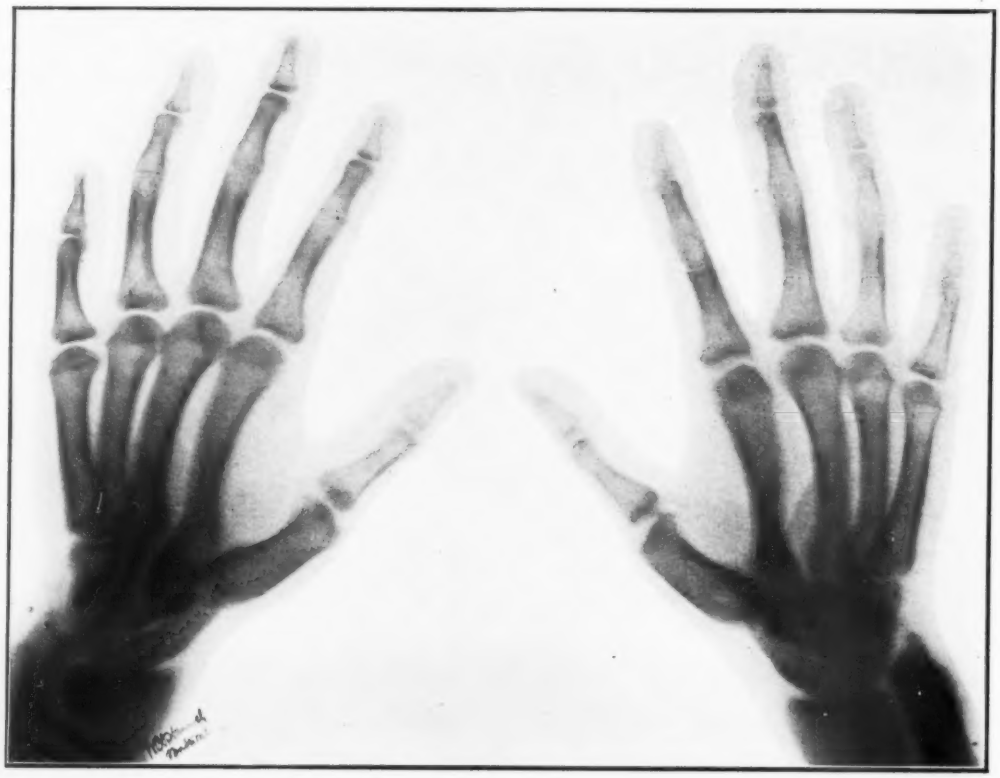
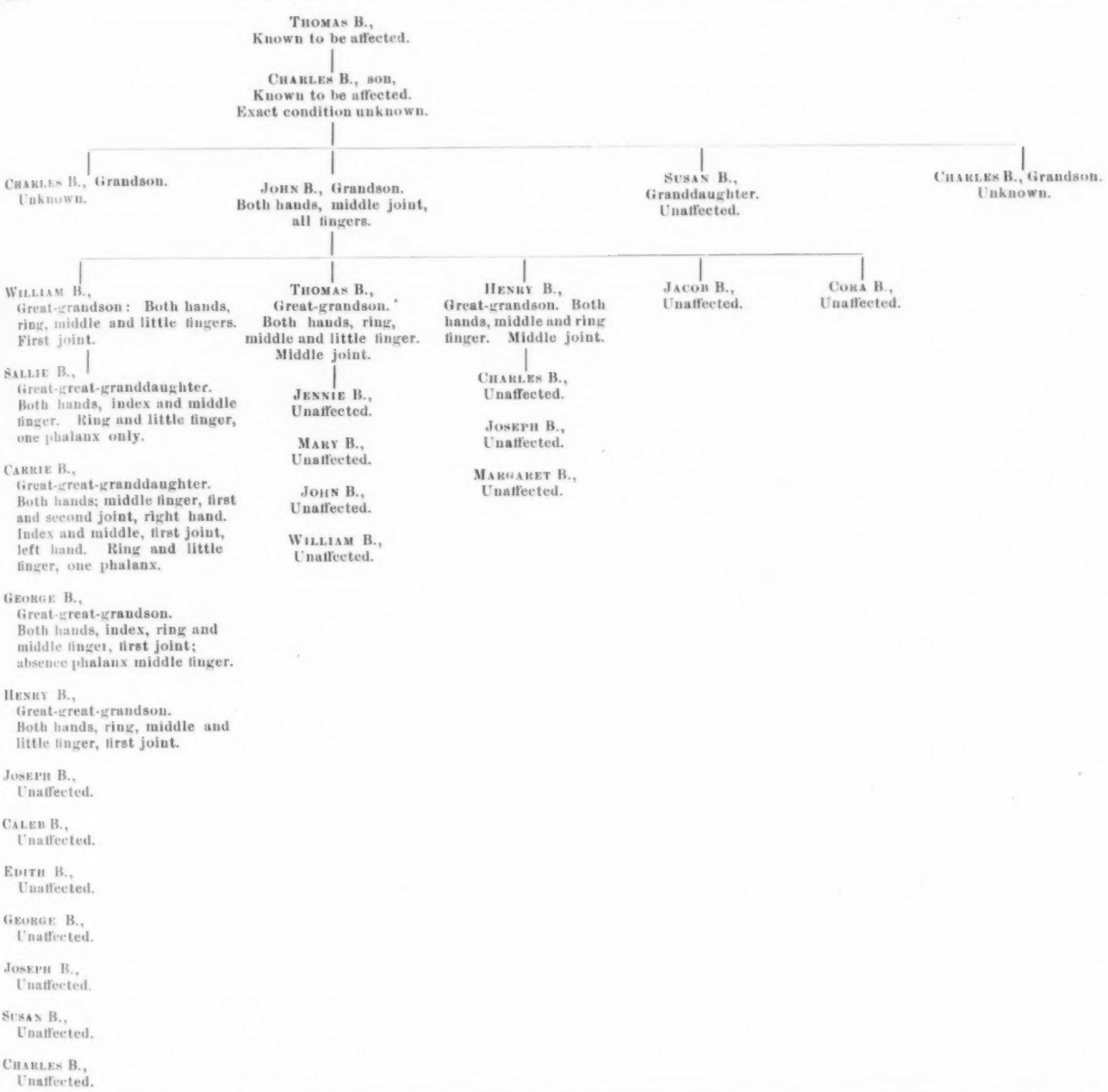


FIG. 4.



NOTE ON THE BASEMENT MEMBRANES OF THE TUBULES OF THE KIDNEY.

By Franklin P. Mall.

Professor of Anatomy, Johns Hopkins University.

In an earlier publication upon reticulated tissues in general the statement was made that the whole framework of the kidney, including the basement membranes, from the capsule to the pelvis, is formed by one mass of anastomosing fibrils, and that the sharp borders of the fibrils mark the outlines of the tubules to form the basement membranes which in ordinary sections appear to be homogeneous.[1] This statement was based upon observations made by digesting frozen

[1] Mall, Abhandl. der math.-phys. classe der Königl. Säch. Geschell. der wissensch., Bd. 16, and Johns Hopkins Hospital Reports, vol. 1.

sections of the kidney, digested in pancreatin, stained with acid fuchsin and differentiated with picric acid. By this method all of the cells and other structures of the kidney are destroyed, leaving only the white fibres and reticulated fibrils which are stained intensely red. This observation has been confirmed by Rühle,[2] who used a method similar to the one I employed. Rühle digested small blocks of kidney (after hardening in alcohol) with pancreatin until all the cells were dissolved, then made sections in paraffin, which were stained upon the slide. By this method the topography of the reticulum is retained much better than is the case in specimens made by the freezing method.

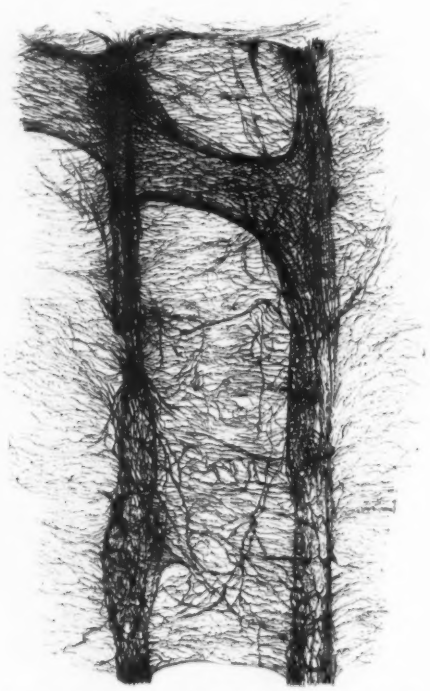


FIG. 1.—Longitudinal section of the framework encircling a kidney tubule digested in pancreatin, stained with acid fuchsin, and differentiated with picric acid. Enlarged 333 times.

The work of Rühle, which is very accurate and extensive, shows quite conclusively that the fibrils obtained by his method, as well as by the freezing method, are identical with those which form the interstitial tissue as seen in ordinary sections.

The observations given above have been confirmed by Disse,[3] who states, however, that the basement membranes of the kidney which have been isolated by means of strong acids always appear to be homogeneous. This he explains by assuming that pancreatic digestion resolves the membrane into fibrils by dissolving the cement substance between them. The strong acids, however, dissolve the interstitial connective tissue but do not affect those fibrils which are stuck together by the cement substance to form basement membranes.

Von Ebner[4] is of the opinion that the fibrillar appearance of the basement membranes of the kidney is due to fine folds in it owing to the method of preparation. He further states that the fibrils of connective tissue between the tubules stain with acid fuchsin while the membranes do not. There is some truth in this statement, for in sections of the kidney which have been macerated and slightly tinged the stained fibres shine through the homogeneous membrane, often making it appear folded. Yet with some care the true nature of these makings is easily determined.

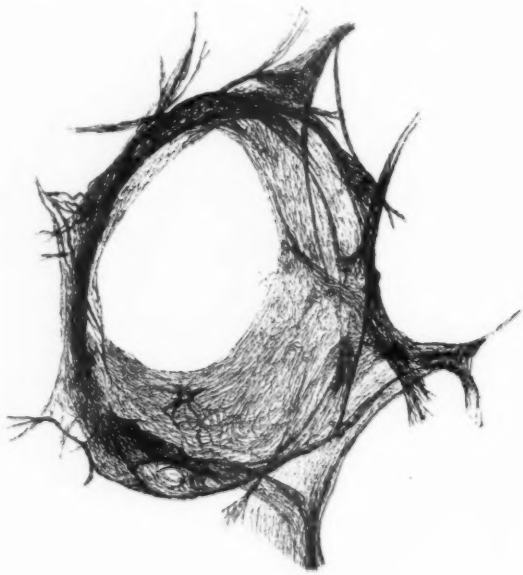


FIG. 2.—Transverse section of the reticulum encircling a kidney tubule prepared as Fig. 1.

Recently, while studying sections of the fresh kidney by means of various methods, I obtained specimens which proved that the observations of Rühle, Disse and myself are correct, so far as they go, but that our conclusions regarding the basement membranes are not correct. The baskets, which I reproduce in Figs. 1 and 2, do exist, are easily obtained by means of pancreatic digestion, but do not form the basement membranes. An additional membrane, the basement membrane, lies within this tube and is totally destroyed by means of pancreatic digestion. The most instructive specimens I obtained were made by macerating frozen sections of the rabbit's kidney in a cold saturated solution of bicarbonate of soda for a number of days, after which most of the cells have been converted into a slimy mass. Shaking the section vigorously in water soon cleared the framework, which was next spread upon a slide and examined. In case most of the cell remnants had been removed the section was dried upon the slide, stained with acid fuchsin, differentiated with picric

[2] Rühle, His's. Archiv, 1897.

[3] Disse, Sitzungsberichte der Geschellsch. zur Beförderung der gesammten Naturwissenschaften zu Marburg, November, 1898.

[4] Von Ebner, Kölliker's Handbuch der Gewebelehre, Bd. 3, S. 374–375.

acid and mounted in balsam. Successful sections prepared in this way show the basement membranes partly filled with the remnants of epithelial cells, the interstitial reticulated connective tissue and the blood-vessels. A portion of such a specimen is shown in Fig. 3.

After specimens of the basement membranes and the reticulum are obtained through maceration in bicarbonate of soda, as described above, they may be treated with various reagents to test their properties. Dilute solutions of HCl and KOH cause the reticulum to swell and become transparent, while the basement membrane and the elastic fibrils accompanying the arteries remain unchanged. But it is shown by the Weigert's elastic tissue stain that the membranes are not elastic, for they do not take on the stain while the elastic tissue fibres do. Furthermore, Mallory's connective tissue stain,[1] stains the reticulum but not the membranes. As far as I have tested the basement membranes they give reactions much like the membranes of elastic fibres, but whether they are identical with them I have been unable to determine.

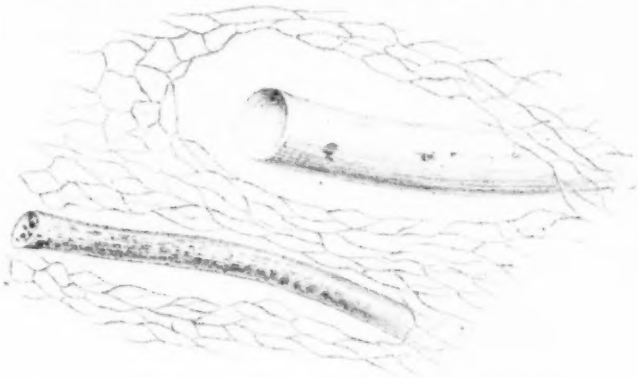


FIG. 3.—Longitudinal section of a kidney tubule with the surrounding reticulum from a specimen macerated in bicarbonate of soda for a week, shaken, dried upon the slide, stained with acid fuchsin and differentiated with picric acid. The basement membrane partly filled with broken epithelial cells and surrounded with reticulum are shown. The drawing is semidiagrammatic.

[1] Mallory, Journal of Experimental Medicine, vol. 5.

A COMPARATIVE STUDY OF THE DEVELOPMENT OF THE GENERATIVE TRACT IN TERMITES.[1]

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The facts here presented furnish a more accurate guide in estimating the status of individuals in the community than has been hitherto available. New light is thrown on hypotheses as to the possible influence of workers and soldiers in the transmission of hereditary characters in these communities. These studies will also be seen to bear on problems of the comparative morphology of the sexual organs of insects. Six species of two genera (Calotermes and Termes) were investigated.

The efferent passages and accessory glands of Termites are simple, as in Thysanura. In Termes flavipes they arise first in larvæ just hatched, in which the mesodermic duct from ovary or testis ends blindly against the ectoderm of the hypodermis. In the female three separate and segmental, unpaired invaginations of the ectoderm appear, one behind another on the ventral mid-line. The pouch of the anterior segment comes into contact with the mesodermic oviducts, that of the next segment later becomes the receptaculum seminis, while the posterior invagination bifurcates at its inner end and eventually forms the colleterial glands. In larvæ preceding those evidently destined to become workers and soldiers, and in adult workers and soldiers, this disconnected segmental condition persists (Fig. 1). In other words, the workers and soldiers exhibit a peculiar arrested, larval stage in the development of the sexual apparatus. In older larvæ of sexual individuals the three, segmental, independent rudiments telescope together and unite to form a vaginal canal with colleterial glands, receptaculum seminis, and mesodermic oviducts opening into it. In the male there

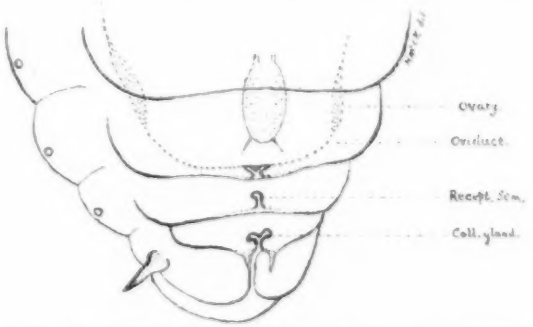

FIG. 1.—Modified camera sketch of ventral aspect of tip of abdomen of Termes flavipes, adult worker or soldier. Female.

is a single median ectodermic invagination into which the paired, mesodermic vesiculæ seminales, and vasa deferentia, eventually open (Fig. 2). In adult workers and soldiers of this sex an arrested larval type is exhibited in the sexual apparatus.

Modifications of this history occur in other species, affecting workers and soldiers especially.

[1] A preliminary abstract presented to the American Morphological Society, December, 1900.

In a species of Eutermes from Jamaica the most extreme modification is found. Not even rudiments of the ectodermic passage and accessory glands appear in workers or soldiers (Nasuti) of this species. The origin of the ectodermic apparatus of sexual individuals of this species is, however, essentially that of the corresponding structures of flavipes.

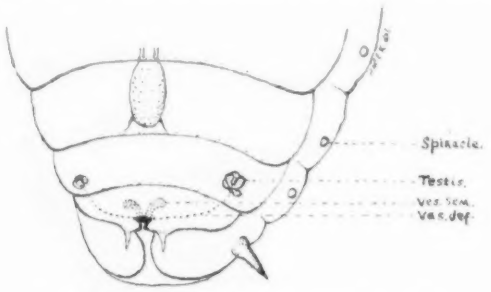

FIG. 2.—Similar sketch of adult worker or soldier. Male.

The condition of the mesodermic sexual gonads, male and female, is very simple in a Jamaican species of Calotermes, a primitive genus of the group. In advanced larvæ and in soldiers the ovary is a series of egg-tubes opening into the oviducts, while the testis is composed of the same number of tubules or follicles arranged serially on the vas deferens.

In T. flavipes and in the Jamaican Eutermes the youngest larvæ exhibit a condition similar to that in Calotermes, which arrangement, it will be observed, bears a suggestive resemblance to the type found in Thysanura.

In the Jamaican Eutermes the workers and soldiers exhibit an extreme arrest of the development of the gonads, which do not proceed beyond the stage found in the youngest larva just hatched.

The adult workers and soldiers of a Japanese species of Termes, unlike T. flavipes, possess gonads not greatly modified from the serial type which seems to be primitive.

In T. flavipes the gonads of older larvæ and of adult workers and soldiers in both sexes lose this primitive type; the tubules of the testicle, for instance, becoming twisted into a globular mass in which the original serial order is obscured.

The gonads of larvæ of sexual individuals, in all species studied, change from the condition at hatching to a type in which the simpler original arrangement is much obscured.

Additional facts with suitable discussions will be published shortly, fully illustrated.

A COMPOSITE STUDY OF THE AXILLARY ARTERY IN MAN.

By J. M. Hitzrot.

(*From the Anatomical Laboratory of the Johns Hopkins University.*)

At the suggestion of Dr. Mall the following records were made from dissections in the Anatomical Laboratory of the Johns Hopkins University during 1898-99 and 1899-1900. Charts[1] were furnished the students with the request that they draw the axillary artery with its branches, etc., as found in their subjects, giving as nearly as possible the origin and distribution of each branch and maintaining the relation to the pectoralis minor and the various bony structures of the axillary region. The charts were merely outlines of the skeleton upon which each student sketched his dissection. When this sketch was finished it was added to or changed by the writer, so that the sketch might, as nearly as possible, represent the artery as it existed in each dissection. Parallel with these drawings a set of notes was kept in which the constant and the unusual branches of the artery were carefully noted. During the year 1898-99, considerable difficulty was experienced with the terms short thoracic, acromio-thoracic, etc., the student in his eagerness to apply these terms to the different branches often overlooking the more important feature, *i. e.*, the distribution of the branch. To obviate this to some extent the charts of this year were compiled and the composite picture thus obtained was drawn and furnished as a guide for the future. The terms before mentioned were kept but special stress was laid upon the origin and distribution of the artery. The results thus obtained were uniformly more satisfactory than those of the previous year.

The charts used in the following tabulations are less than a third of the total number made. The remainder, because of errors in drawing, broken arteries in dissecting, and discrepancies between the notes of the writer and the sketches, were omitted. These omitted charts, in so far as they were of any value, gave practically the same results as were obtained from the tabulation of the correct and more complete charts. In making the tabulations the arbitrary divisions given by the various anatomists were used.

Part I, that portion of the artery extending from the lower border of the first rib to the upper border of the pectoralis minor.

Part II, that portion of the artery which is beneath the pectoralis minor.

Part III, that portion of the artery which extends from the lower border of the pectoralis minor to the lower border of the tendons of the teres major and latissimus dorsi.

During the first tabulation separate tables were made for the right and left sides to determine whether the origin and distribution differed on the two sides. As the only difference found was in the presence or absence of the long thoracic artery this distinction was dropped, the relative difference consisting in the more constant presence of the long thoracic artery on the left side.

[1] Bardeen, Outline Record Charts used in the Anatomical Laboratory of the Johns Hopkins University, Johns Hopkins Press, Baltimore, 1900.

The charts themselves conveniently fall into different types, that is, the artery in a certain number of instances gives off its branches from the same divisions of the arterial trunk and these branches are distributed to the same regions. The 47 charts here tabulated fall into 7 types, type I being present in 20 cases; type II in 9 cases; type III in 7 cases; type IV in 4 cases; type V in 3 cases; and types VI, VII each in 2 cases.

Type I (Fig. 1 and Table I).

This type, the most constant found in the laboratory during the two years the dissections were observed, differs from the text-book descriptions by the absence of the long thoracic artery. The area ordinarily supplied by this artery, accord-

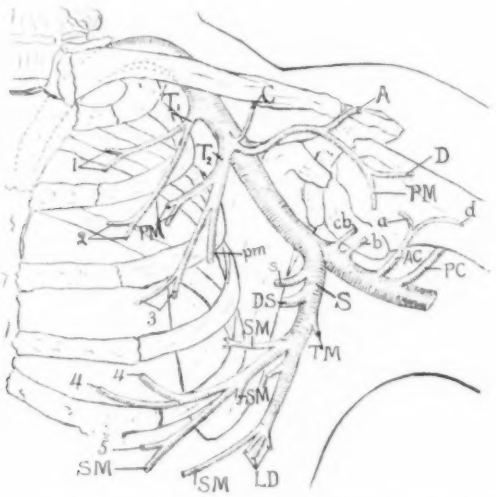

Fig. 1.—Type I of the axillary artery. Present 20 times in 47 cases. *A*, Ramus acromialis; *a*, Ramus ascendens; *AC*, A. circumflexa humeri anterior; *b*, M. biceps; *C*, R. clavicularis; *cb*, M. coraco-brachialis; *D*, M. deltoideus; *d*, Ramus anastomoticus; *DS*, A. circumflexa, scapulæ, (dorsal scapular); *LD*, M. latissimus dorsi; *P*, R. pectoralis; *PC*, A. circumflexa humeri posterioris; *PM*, M. pectoralis major; *pm*, M. pectoralis minor; *S*, A. subscapularis; *s*, M. subscapularis; *SM*, M. Serratus anterior (magnus); *SP*, A. profunda brachii, (superior profunda); *T*¹, A. thoracalis suprema; *T*², A. thoraco-acromialis; *T*³, A. thoracalis lateralis; *TM*, M. teres major; *1*, *2*, *3*, *4*, *5*, 1st, 2d, 3d, 4th and 5th intercostal spaces.

ing to text-books, being supplied by branches from the acromio-thoracic and subscapular arteries. The branches in this type can be conveniently arranged in the following schema:

- Part I.
  - 1. Superior thoracic.
  - 2. Acromio-thoracic.
    - 1. Thoracic branch.
    - 2. Acromio-humeral branch.
    - 3. Clavicular.
- Part II. No branches.
- Part III.
  - 1. Subscapular.
    - 1. Dorsal scapular.
    - 2. Muscular branches.
    - 3. Anterior.
    - 4. Posterior.
  - 2. Anterior circumflex.
    - Ascending branch.
    - Anastomotic.
  - 3. Posterior circumflex.
    - Muscular.
    - Anastomotic.
  - 4. Muscular branches.
    - Coraco-brachialis.
    - Biceps.

The superior thoracic (A. thoracalis suprema) rises just below subclavius muscle and crosses the first interspace, ending in it and in the second interspace. The origin of the artery is remarkably constant in this type (19 times in 20 cases), it supplies the muscles in the first and second interspaces.

The acromio-thoracic (A. thoraco-acromialis) rises from Part I, about midway between the clavicle and upper border of the pectoralis minor, runs almost directly anteriorly and divides into the (1) thoracic branch, (2) the acromio-humeral and (3) clavicular branch.

This artery is the most constant in this type, being present in all 20 cases. The thoracic branch turns downward beneath the pectoralis minor, giving off branch to the pectoralis major and minor, and to the second and third intercostal spaces and the overlying skin. The acromio-humeral branch runs upward and outward across the costo-coracoid membrane over the coracoid process of the scapula and gives a branch to the acromion and accompanying the cephalic vein between the deltoid and pectoralis major breaks into branches, supplying these two muscles and the surrounding fascia and skin. The clavicular branch is a small branch which turns upward to supply the subclavius muscle.

The subscapular artery arises from the axillary trunk at the lower border of the subscapularis muscle and takes a downward and inward course through the axilla. Near its origin it gives off a branch to the subscapular muscle and a large branch, the dorsal scapular, which passes through the triangular space formed by the subscapularis, teres major and long head of the triceps, to the dorsum of the scapula, supplying the muscles of that region. A small branch to the teres major muscle then comes from the subscapular trunk as it crosses that muscle, and before it splits into the thoracic or anterior branch and its posterior or muscular branch. The thoracic branch crosses the base of the axilla from the back to the front and supplies the serratus magnus, the fourth and fifth interspaces, and the adjacent skin. The posterior branch continues the downward and backward course of the subscapular trunk to end in the serratus magnus, and the latissimus dorsi, giving off numerous branches to these muscles.

Two small muscle branches are given off to the coraco-brachialis and biceps.

From the anterior portion of the axillary trunk a small artery, the anterior circumflex, rises, passes beneath the coraco-brachialis and biceps and sends a branch to the joint by way of the bicipital groove and a branch around the arm to anastomose with the posterior circumflex artery. In its course it gives off branches to the overlying muscles. At about the same level and from the posterior portion of the axillary artery the posterior circumflex takes its origin, passes downward and backward through the space bounded by the teres minor, long head of the triceps, teres major and the humerus, winds around the neck of the humerus, supplying the deltoid, the joint, the triceps, and the adjacent skin

and anastomoses with the anterior circumflex artery and superior profunda artery.

Type II (Fig. 2 and Table II).

The branches in type II are conveniently arranged according to the following plan:

- Part I. Superior thoracic.
- Part I. Acromio-thoracic.
  - 1. Thoracic branch.
  - 2. Acromio-humeral branch.
  - 3. Clavicular branch.
- Part II. Long thoracic.
- Part III. Subscapular.
  - 1. Dorsal scapular.
  - 2. Muscular branches.
  - 3. Posterior branch.
- Part III. Trunk.
  - Anterior circumflex.
  - Posterior circumflex.

This type differs from type I only by the presence of a branch from the part II of the axillary trunk and corresponds

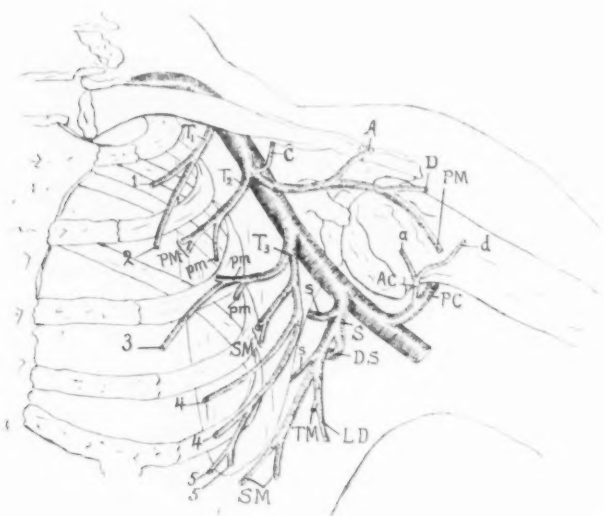

Fig. 2.—Type II of the axillary artery. Present 9 times in 47 cases.

with the description of the axillary artery usually given in the text-books. This branch from the second part of the artery bears the name long thoracic (A. thoracalis lateralis). It takes its origin beneath the pectoralis minor, courses downward along the lower border of this muscle, supplying it, the serratus magnus, and the third, fourth and fifth interspaces. In its course it gives off small branches to the fascia of the axilla, and terminal branches which piercing the pectoralis major terminate in the overlying skin. The other arterial branches have the same origin and distribution as described in type I, except that the intercostal areas of the thoracic branch of the acromio-thoracic artery and the thoracic branch of the subscapular artery are replaced wholly or in part by this branch from part II. The anterior and posterior circumflex arteries arise by a common trunk but otherwise their course and distribution correspond to the description given under type I.

Type III (Fig. 3 and Table III).

- Part I. Superior thoracic
- Part I. Acromio-thoracic.
  - Thoracic br.
  - Acromio-humeral.
  - Clavicular.
- Part II. Subscapular.
  - 1. Thoracic branch.
  - 2. Muscular branches.
  - 3. Posterior circumflex.
  - 4. Dorsales scapulae.
  - 5. Anterior branch.
  - 6. Posterior "
- Part III. Anterior circumflex.
  - Ascending.
  - Anastomotic.

The branches from part I are similar in their origin and distribution to those described in type I. From part II a large subscapular artery takes its origin. It immediately gives off a branch (thoracic) which supplies the serratus magnus and crossing the axilla beneath the pectoralis minor

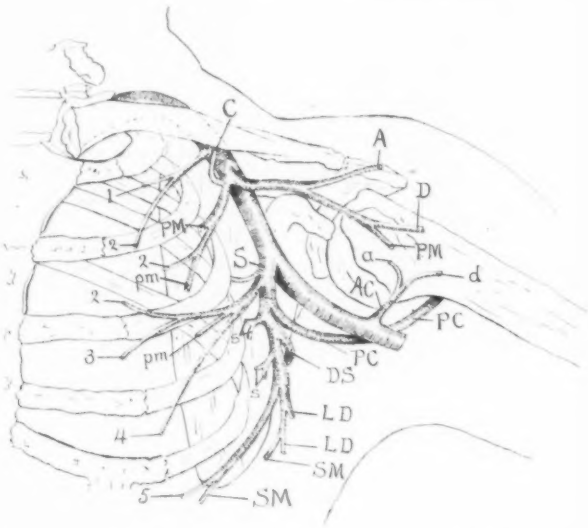

Fig. 3.—Type III of the axillary artery. Present 7 times in 47 cases.

supplies that muscle and the second, third and fourth interspaces. Just above the lower border of the pectoralis minor a larger branch descends which gives off the posterior circumflex dorsal scapular, and muscular branches and terminates in an anterior branch to the fifth interspace and serratus and a posterior branch to latissimus dorsi and serratus. From the drawing and description the thoracic branch of this artery can be seen to correspond with the description of the "long thoracic" artery, while the lower descending branch corresponds to the description usually allotted to the subscapular artery. The artery, however, can be better described as the subscapular artery because, as is seen in type I, the subscapular artery does supply the mid-thoracic region and because the long thoracic artery is so often absent. The anterior circumflex has the same origin and distribution as that given it under type I.

TYPE IV (FIG. 4 AND TABLE IV).

In type IV the acromio-thoracic artery commonly found in part I is found arising from part II of the axillary trunk. The distribution of the branches in this type is similar to that given under type I (the superior thoracic supplying the

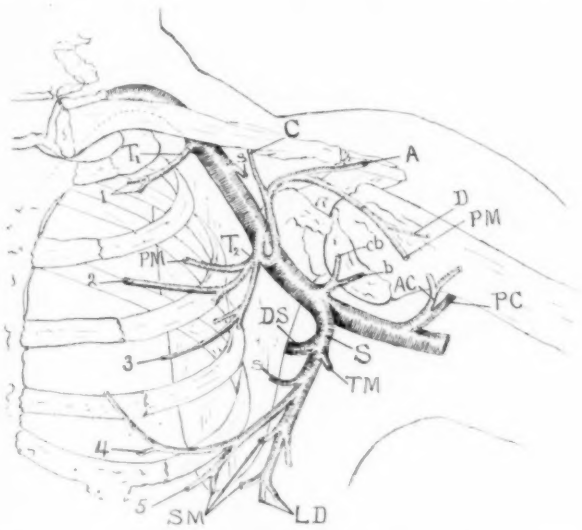

FIG. 4.—Type IV of the axillary artery. Present 4 times in 47 cases.

first interspace only), with an added branch to the subscapularis muscle which, taking its origin from part I, turns backward and downward, passes between the trunks of the brachial plexus and ends in the subscapularis muscle.

- Part I.
  - Superior thoracic.
  - Branch to M. subscapularis.
- Part II. Acromio-thoracic.
  - Thoracic.
  - Acromio-humeral.
    - Clavicular.
    - Acromial.
    - Muscular.
- Part III.
  - Muscular branch.
    - Coraco-brachialis.
    - Biceps.
  - Subscapular.
    1. Muscular.
    2. Dorsal scapular.
    3. Anterior.
    4. Posterior.
  - Trunk.
    - Anterior circumflex.
    - Posterior "

TYPE V (FIG. 5 AND TABLE V).

From the table and drawing it is readily seen that practically the whole pectoral area, the thoracic and subscapular regions, are supplied by an artery given off from part II of the axillary artery. From the table it will be noticed that this was the case twice, while in the third case two arteries with the same distribution as the above mentioned trunk have separate origins from the main trunk. In this latter case the origins of the two arteries supplying this whole area were so close together that for practical purposes they can be called a common trunk and are incorporated as such in the drawing of this type. It is important, however, to remember that type V may be represented by two branches rising close together from part II, as is seen by the drawing given for that type. In one case the trunk had an even larger area of distribution than is shown in the drawing, the anterior and posterior circumflex regions being supplied by

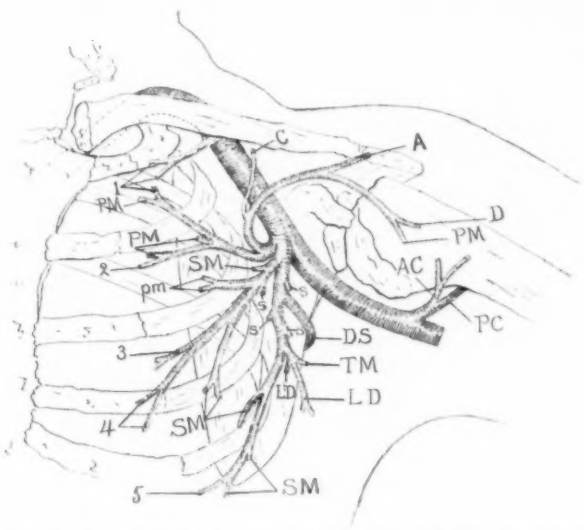

FIG. 5.—Type V of the axillary artery. Present 3 times in 47 cases.

branches from the large trunk from part II. These two variations in type V are given because future research may show that one of these variations is more common than that found to be most frequent in my observations.

- Part I. Superior thoracic (small).
- Part II.
  1. Acromio-thoracic.
     - Thoracic branch.
     - Acromio-humeral.
       - Clavicular.
       - Acromial.
       - Muscular.
  2. Long thoracic.
  3. Subscapular.
     - Muscular.
     - Dorsal scapular.
     - Anterior branch.
     - Posterior "
- Part III.
  - Anterior circumflex.
  - Posterior "

In the above schema I have called the branches by their adopted names, and the distribution of each branch from this trunk is similar to the distribution described under types I and II.

TYPE VI (FIG. 6 AND TABLE VI).

This type existed but twice in the dissections observed and is remarkable for the number of branches which arise from part I.

- Part I.
  - Superior thoracic.
  - Acromio-thoracic.
    - Clavicular.
    - Acromial.
    - Deltoid.
  - Pectoral branch.
    - Muscular.
    - Intercostal.
  - Long thoracic.

Part II. No branches.

Part III.
- Subscapular
  - Dorsal scapular.
  - Muscular.
  - Anterior branch.
  - Posterior "
- Trunk.
  - Anterior circumflex.
  - Posterior "

The superior thoracic is small, giving a twig to the upper digitations of the serratus and ends in the first interspace.

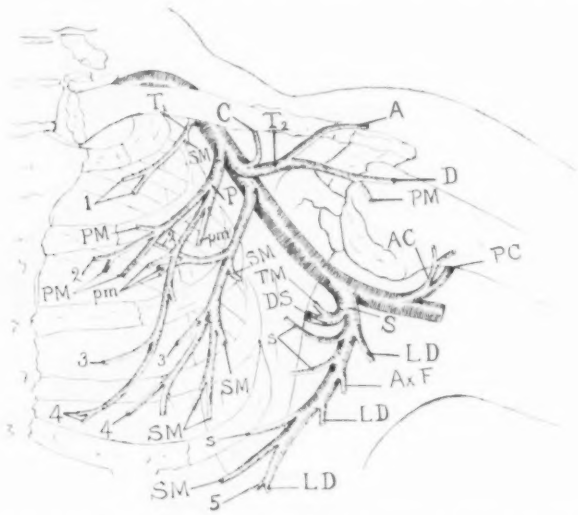

FIG. 6.—Type VI of the axillary artery. Present 2 times in 47 cases.

This type shows to a marked degree a variation which occurs in the origin of the acromio-thoracic artery, *i. e.* a separate origin of its pectoral or thoracic branch, while the artery designated as the acromio-thoracic is merely the acromio-humeral division of that artery. From the table it will be noticed (line 2, table VI) that the thoracic branch of the acromio-thoracic artery was present in one case. My notes on this case mention the fact that this branch was extremely small and that the area usually completely supplied by it receives most of its blood-supply from a branch rising from the main trunk. This pectoral branch rises from the trunk slightly above or just adjacent to the origin of the acromio-thoracic artery, courses downward and forward, supplying the pectoralis major and minor and the second, third and fourth intercostal spaces. The long thoracic artery, except for its origin, is similar to that described under type II.

The subscapular artery is the same as that of type I, and the trunk common to anterior and posterior circumflex arteries is the same as that of type II.

TYPE VII (FIG. 7 AND TABLE VII).

Type VII occurred but twice in the records made. In this type, as in type VI, the thoracic branch of the acromio-humeral artery is very small, being represented by a small twig to the pectoralis minor, while its area of distribution is supplied by a branch from the large subscapular artery; in type VI it was supplied by a separate branch from the axillary trunk.

Part I.
- Acromio-thoracic.
  - Thoracic.
  - Clavicular.
  - Acromio-humeral.
    - Acromial.
    - Muscular.
- Subscapular.
  - Pectoral.
    - Upper division.
    - Lower "
  - Muscular.
  - Dorsal scapular.
  - Anterior division.
  - Posterior "

Part II. No branches.

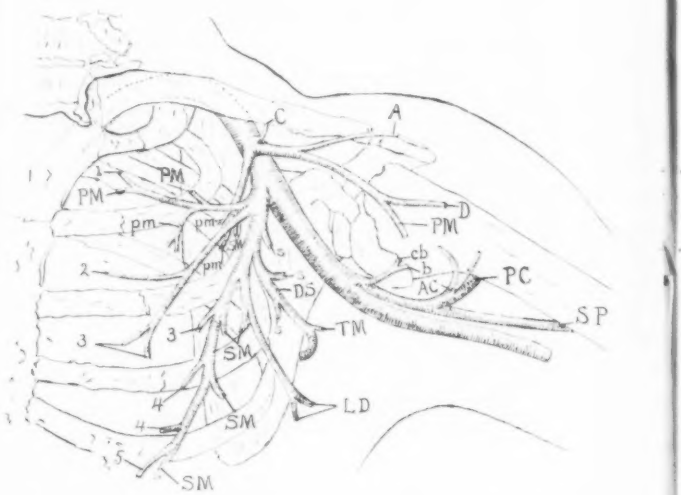

FIG. 7.—Type VII of the axillary artery. Present 2 times in 47 cases.

Part III. Trunk.
- Muscular branch.
- Trunk.
  - Anterior circumflex.
  - Posterior "
- Superior profunda.

In this type the superior thoracic is absent and its area of distribution is supplied by the subscapular.

The cromio-thoracic is the same as type I; while the thoracic or pectoral branch is small. The subscapular arises well above the upper border of the pectoralis minor, turns downward beneath that muscle and supplies the whole thoracic, pectoral and subscapular regions. Part III gives off a large trunk which runs parallel to the main artery, gives off branches to the coraco-brachialis and biceps, and a trunk which immediately splits to form the anterior and posterior circumflex arteries (distribution similar to that under type I), and then turning down, out and back passes through the musculo-spiral groove to become the superior profunda artery.

In the first part of this paper the types into which the axillary artery fell are discussed and it is my intention in this portion to discuss the individual branches with their origin, distribution and variations.

Superior Thoracic.—This artery was remarkably constant, appearing 40 times in the 47 cases here tabulated. In the 7 cases in which it was absent it was supplied by the acromio-thoracic in 4 cases. This is the condition described as normal by Testut, Sappey and Cruveilhier. In 2 cases the subscapular supplied its area (type III), and in one case a large trunk from part II of the axillary (type V). The artery was most frequently distributed to the first and second interspaces,

as in type I. In 4 cases, however, the artery was distinctly longer than normal and rising high up in the axilla, turned directly downward and passed along the lateral thoracic wall, supplying the interspaces from 1 to 4 (in 2 cases the 5th also) and the serratus magnus muscle. This artery was in close relation to the posterior thoracic nerve, being anterior to it and separated from it by an accompanying vein. As far as can be ascertained, this artery has not been described before. In one of these cases the artery was of considerable size and gave branches to the glandular contents of the axilla and sent numerous branches forward in the intercostal spaces. In some respects it corresponds to the long thoracic, but owing to its presence in a case in which the long thoracic was present also, and its origin near that ascribed to the superior thoracic, it has been included in the description of the superior thoracic artery.

Acromio-thoracic Artery.—This branch, the most constant of the axillary subdivisions, came from part I in 40 cases, from part II in 5 cases and in the remaining 2 cases came from the trunk common to it, the subscapular and long thoracic arteries (type V). For convenience of description the following schema of the acromio-thoracic artery will be found very useful.

Acromio-thoracic. { Pectoral branch. Clavicular branch. Acromio-humeral branch.

The pectoral branch of this artery was present 43 times in the 47 dissections. In the 4 cases in which it was absent its area of distribution was supplied by a pectoral branch from the axillary trunk in 3 cases (type VI), and in one case from the subscapular (type VII), which shows the thoracic branch present although small. This pectoral division of the acromio-thoracic trunk is very variable in size, occasionally being large, in which case it supplies the pectoral muscles, the second to fifth interspaces, and the serratus magnus and latissimus dorsi. In those cases in which there is a long thoracic artery present, it is smaller than in the first instance and is limited to the pectoral muscles and the upper interspaces. Occasionally it is very small, being merely a muscular branch to the pectoral muscles, and its area in this case is more completely supplied by branches from the long thoracic, the subscapular or by pectoral branches from the main trunk.

The clavicular branch is a small artery which was present 43 times in the 47 dissections. In the 4 cases in which it is absent 3 cases show no artery to this area from any of the axillary subdivisions; in one case it was supplied by a branch from the main trunk. The acromio-humeral branch is the most constant subdivision of the acromio-thoracic, and in those cases in which the pectoral branch is absent, it, with the clavicular branch, forms the acromio-thoracic artery. In the discussion of this subject under type VI, I have suggested that this artery is merely the acromio-humeral artery and not the acromio-thoracic, since it lacks the thoracic or pectoral portion. Its distribution is also constant. In one case the humeral or descending branch was small, the anterior circumflex artery in this case being large and sending off large ascending branches to the deltoid and clavicular portion of the pectoralis major. In 3 cases a branch is given off to the subscapular muscle.

The Long Thoracic.—This artery was present only 11 times as a separate branch from the axillary trunk (types II and VI) and it was with this artery that the most trouble arose in tabulating the dissections. The 11 cases here tabulated represent a large majority of the number found in all the charts received. In discussing the question of the absence or presence of a major branch from part II, it is found that in 24 cases no major branch is found, while in 23 cases there is a major trunk.

Instances in which there are no arteries from part II, type I, 20; type VI, 2; type VII, 2.

Instances in which there are arteries from part II, type II, 9; type III, 7; type IV, 4; type V, 3.

The cases in which the artery, arising from part II of the axillary is the long thoracic, are, however, less frequent, that artery being present only in the 9 cases represented by type II.

The long thoracic artery, as described by His, arises beneath the pectoralis minor, courses downward upon the serratus magnus to the fifth or sixth interspace, supplying that muscle. The external mammary branches pierce the pectoralis major and supply the skin in the mammary region. According to Testut, it arises beneath the pectoralis minor, courses obliquely downward, inward and forward along the lateral thoracic wall between the pectoralis major and the serratus magnus as far as the fifth, sixth or seventh interspace, where it terminates in anastomosis with the intercostal arteries. As it descends it gives off numerous collateral branches to the axillary glands, the subscapular muscles, the serratus magnus, pectoralis major and minor, the intercostal spaces, the mammary gland, and the antero-lateral region of the thorax. According to Quain, the long thoracic artery arises beneath the pectoralis minor, is directed downwards and inwards along the lower border of that muscle and is distributed to the pectoral muscle, the serratus magnus, and the breast, forming anastomosis with the intercostal arteries.

From the above descriptions it is readily seen how variable the distribution of the artery may be. My cases correspond more nearly to the description given by Quain, although in 3 of the cases the artery corresponded with the description given it by Testut.

The Subscapular Artery.—This artery varied considerably in its place of origin, coming from part I in 2 cases, from part II in 8 cases, from part III in 35 cases, and in 2 cases from the trunk common to it, the long thoracic and acromio-thoracic from part II. The common distribution of this artery is that given it under type I. It may, however, vary considerably, as is seen from the description given it in type III. In four cases the artery was small, being practically only the dorsal scapular artery. In these cases its remaining areas were supplied by the long thoracic in 3 cases, and by a large thoracic branch from the acromio-thoracic in one case.

(See table type I). The anterior and posterior circumflex areas are also supplied by this artery, the former in 2 cases and the latter in 9 cases. In one case it also gave rise to the superior profunda artery. The cases in which the subscapular included arteries usually arising from the axillary or brachial trunks can be classified as follows:

Subscapular + posterior circumflex and superior profunda,
Subscapular + posterior circumflex,
Subscapular + anterior circumflex,
Subscapular + anterior and posterior circumflex.

The Anterior Circumflex.—The origin of this artery was relatively constant, coming from part III as a separate branch in 22 cases and from a trunk common to it and the posterior circumflex in 21 cases. In the remaining 4 cases it took its origin from the subscapular in 2 cases, from a trunk common to it, the posterior circumflex and superior profunda in 1 case, and from the large trunk common to all the arteries in 1 case. Its distribution, as that given it under type I, was constant except in that case in which it was given off from the subscapular and supplied the area usually supplied by the humeral branch of the acromio-thoracic artery, that branch being small in this particular case. The cases in which the anterior circumflex is united with arteries ordinarily arising from the main artery may be grouped as follows:

1.	Anterior and posterior circumflex,	21 cases.
2.	Subscapular and anterior circumflex,	1 case.
3.	" " " and posterior circumflex,	1 "
4.	Trunk. { Anterior circumflex. Posterior circumflex. Superior profunda }	1 "
5.	Trunk. { Acromio-thoracic. Long thoracic. Subscapular. Anterior circumflex. Posterior " }	1 "

The Posterior Circumflex.—This artery was perhaps the most variable in origin of the axillary subdivisions being, however, constant in its distribution (see type I).

The places of origin are as follows:

1.	From axillary artery.	13 cases.
2.	Trunk. { Anterior circumflex. Posterior " }	21 "
3.	Subscapular.	9 "
4.	Trunk. { Posterior circumflex. Superior profunda. }	2 "
5.	Trunk. { Acromio-thoracic. Long thoracic. Subscapular. Anterior circumflex. Posterior " }	1 "
6.	Brachial artery.	1 "

The 3 trunks recorded in the table have been described elsewhere in this paper and are sufficiently clear from the table itself. The remaining muscular, cutaneous and intercostal branches are infrequent and may or may not occur. When present they are large or small as the case necessitates. The branch labelled " axillary fascia " is that which is usually described as the alar thoracic artery. It was present 8 times, its area being supplied by the larger subdivisions of the main arteries in their courses through the axilla.

The Posterior Scapular.—This artery arose from the axillary artery in 5 cases. The artery in its course turns backward, passes either between the trunks of the brachial plexus or passes over them, courses along the superior margin of the scapula and then turns downward to pass parallel to the vertebral margin of the scapula. In its course it gives branches to the subscapularis, levator anguli scapulæ, trapezius, rhomboid major and rhomboid minor, supraspinatus and infraspinatus.

The suprascapular artery was found arising from the axillary artery in one case. In one case the superior profunda was given off in the axilla. In two cases not included in these records the axillary artery divided into the radial and ulnar in the axilla, and in these cases the anterior and posterior circumflex arteries and the superior profunda were given off by the radial.

The conclusions to be drawn from this study are:

(1) That while the origin of the subdivisions of the axillary artery varies, the distribution is practically constant.

(2) That type I, as here described, is the ordinary form in which the axillary artery is found.

(3) That the long thoracic artery and alar thoracic arteries are most frequently absent and that their areas of distribution are supplied by the adjacent branches from the main artery.

TABLE SHOWING THE ORIGIN AND DISTRIBUTION OF THE BRANCHES OF THE AXILLARY ARTERY IN FORTY-SEVEN CASES.

BRANCH.	Origin.			Distribution.																								
	Part I.	Part II.	Part III.	1st Intercostal space.	2nd Intercostal space.	3rd Intercostal space.	4th Intercostal space.	5th Intercostal space.	Pectoralis major.	Pectoralis minor.	Pectoralis major, acromion, and deltoid.	Subclavius and clavicle.	Subscapularis.	Dorsal region of scapula.	Serratus magnus.	Latissimus dorsi.	Teres major.	Posterior circumflex.	Anterior circumflex.	Axillary glands and fascia	Coraco-brachialis.	Biceps.	Articular.	Posterior region of scapula.	Superior profunda.	Teres minor.	Deltoid.	Suprascapular.
Superior thoracic	40	..	..	40	26	9	4	2	..	..	..	..	1	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..
Acromio-thoracic	40	5	..	7	24	24	6	2	41	38	45	43	3	..	2	1	..	..	..	3	..	..	..	..	..	..	..	..
Long thoracic	2	9	..	1	4	11	11	5	1	8	..	..	5	..	11	3	..	..	..	..	..	..	..	..	..	..	..	..
Subscapular	2	8	35	2	6	22	32	41	1	8	..	..	42	45	41	41	23	9	2	7	..	..	..	..	1	1	..	..

BRANCH.	ORIGIN.			DISTRIBUTION.																											
	Part I.	Part II.	Part III.	1st Intercostal space.	2nd Intercostal space.	3rd Intercostal space.	4th Intercostal space.	5th Intercostal space.	Pectoralis major.	Pectoralis minor.	Pectoralis major, acromion, and deltoid.	Subclavius and clavicle.	Subscapularis.	Dorsal region of scapula.	Serratus magnus.	Latissimus dorsi.	Teres major.	Posterior circumflex.	Anterior circumflex.	Axillary glands and fascia	Coraco-brachialis.	Biceps.	Articular.	Posterior region of scapula.	Superior profunda.	Teres minor.	Deltoid.	Suprascapular.
Anterior circumflex	..	..	32	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	32	..	..	..	..	..	..	..	..	..
Posterior circumflex	..	..	13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	13	..	..	..	..	..	..	..	..	..	..
Trunk common to anterior and posterior circumflex	..	..	21	..	..	..	..	..	..	..	..	..	..	..	..	..	..	21	21	..	..	..	..	..	..	..	..	..
Trunk common to circumflex arteries and superior profunda	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	1	..	1	1	..	..	2	..	..	..
Common trunk	..	..	..	..	..	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	..	..	..	..	..	..	..	..
To subscapularis	15	5	1	..	..	2	2	2	2	2	2	2	21	2	2	2	2	2	2	..	..	..	..	..	..	..	..	..
To serratus magnus	1	..	..	1	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
To pectoralis major	2	2	..	..	..	..	..	..	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
To pectoralis minor	3	6	..	..	..	..	..	..	..	9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pectoral branch	5	1	..	..	4	3	2	..	5	5	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
To subclavius and clavicle	1	..	..	2	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
To axillary fascia	1	2	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8	..	..	..	..	..	..	..	..
Articular	2	3	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9	..	..	..	..	..
1st and 2nd interspaces	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2nd interspace	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2nd and 3rd interspaces	1	1	..	1	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
To coraco-brachialis	..	1	19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..
To biceps	..	1	19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..
To deltoid	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..
Posterior scapular	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..
Suprascapular	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
Superior profunda	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..

TYPE I, 20 CASES.

BRANCH.	ORIGIN.			DISTRIBUTION.																						REMARKS.
	Part I.	Part II.	Part III.	1st Interspace.	2nd Interspace.	3rd Interspace.	4th Interspace.	5th Interspace.	Pectoralis major.	Pectoralis minor.	Pectoralis major, acromion deltoid.	M. subclavius.	M. subscapularis.	Dorsal region of scapula	M. serratus magnus.	M. latissimus dorsi.	M. teres major.	Posterior circumflex.	Anterior circumflex.	Axillary glands and fascia.	M. coraco-brachialis.	M. biceps.	Articular.	Posterior region of scapula	Superior profunda.	Teres minor.	
1. Superior thoracic	19	..	..	19	14	5	1	..	..	..	..	..	..	1	..	2	..	..	..	..	..	..	..	..	..	..	In the absent case the region was supplied by the acromio-thoracic artery.
2. Acromio-thoracic	20	..	..	2	12	15	5	2	20	20	20	19	2	..	2	1	..	..	..	..	..	..	..	..	..	..	..	
3. Subscapular	..	..	20	..	..	12	19	19	..	1	..	..	17	20	19	19	12	4	..	..	..	..	..	..	..	1	1	
4. Anterior circumflex	..	..	12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	12	..	1	..	..	..	..	..	..	8 times from a branch common to circumflex arteries (see line 6).
5. Posterior circumflex	..	..	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	7	..	..	..	..	..	..	..	..	..	8 times from branch common to circumflex arteries, 4 times from subscapular, 1 case from brachial artery (see lines 3 and 6).
6. Trunk common to anterior and posterior circumflex arteries	..	..	8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8	8	..	..	..	..	..	..	..	..	
7. To M. subscapularius	8	3	..	..	..	..	..	..	..	..	..	..	11	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
8. To pectoralis major	2	2	..	..	..	..	..	..	..	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
9. To pectoralis minor	3	2	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
10. Axillary glands and fascia	1	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	
11. Articular	2	1	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	
12. 2nd and 3rd interspaces	1	1	..	..	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	
13. Coraco-brachialis	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	
14. Biceps	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	
15. Posterior scapular	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	

TYPE II, 9 CASES.

BRANCH.	Origin.			Distribution.																						REMARKS.
	Part I.	Part II.	Part III.	1st Interspace.	2nd Interspace.	3rd Interspace.	4th Interspace.	5th Interspace.	Pectoralis major.	Pectoralis minor.	Pectoralis major, acromion, deltoid.	Subclavius.	M. subscapularis.	Regio dorsalis scapulae.	M. serratus magnus.	M. latissimus dorsi.	M. teres major.	Posterior circumflex.	Anterior circumflex.	Axillary glands and fascia	Coraco-brachialis.	Biceps.	Articular.	Posterior region of scapula.	Superior profunda.	Suprascapular.	
1. Superior thoracic	7			7	4	2	1																			Absent twice, supplied by acromio and long thoracic (see lines 2 and 3).
Acromio-thoracic	9			9	3	2			7	6	9	8														Pectoral branch absent twice, area supplied by long thoracic (line 3) and pectoral branch (line 11).
3. Long thoracic	9			1	2	9	9	5	1	6			5		9	3				3						Large in 3 cases, supplying the subscapular area in part (see line 4).
4. Subscapular		9					3	6					9	9	6	6	6	1	1	1						Small in 3 cases, being confined to dorsal and scapular region principally (see text).
5. Anterior circumflex		4																4	4							For remaining place of origin see lines 4 and 7.
6. Posterior circumflex		3																3								For remaining places of origin see lines 4, 7 and 8.
7. Trunk, common to anterior and posterior circumflex arteries		4																4	4							For other origins of circumflex arteries, see lines 4, 5, 6 and 8.
8. Trunk		1																1						1		
9. Branch to M. subscapularis	3	1	1										5													
10. To serratus magnus	1														1											
11. Pectoral branch	2	1		1	1				3	2																
12. Articular		1																					1			
13. Coraco-brachialis		3																		3						
14. Biceps		3																			3					
15. Suprascapular	1																								1	

TYPE III, 7 CASES.

1. Superior thoracic	6			6	5	2	2	2																		Absent once, supplied by acromio-thoracic and subscapular.
2. Acromio-thoracic	7			2	4	3			7	6	7	7														
3. Subscapular		7		1	4	5	7	7		5			7	7	7	7		3		2						
4. Anterior circumflex			4																4							For 3 remaining cases see line 6.
5. Posterior circumflex			1															1								From subscapular in 3 cases. From trunk (line 6) in 3 cases.
6. Trunk, common to anterior and posterior circumflex			3															3	3							See lines 4 and 5.
7. M. subscapularis	2												2													
8. M. coraco-brachialis		1	2																	3						
9. M. biceps		1	2																		3					
10. Articular		1	1																			2				
11. 1st and 2nd interspaces	2			2	2																					
12. Br. to deltoid		1	1																						2	
13. M. pectoralis minor		1								1																
14. Axillary fascia			1																1							
15. Superior profunda			1																					1		
16. Posterior scapular	1																						1			

TYPE IV, 4 CASES.

BRANCH.	ORIGIN.			DISTRIBUTION.																			REMARKS.
	Part I.	Part II.	Part III.	1st Interspace.	2nd Interspace.	3rd Interspace.	4th Interspace.	5th Interspace.	Pectoralis major.	Pectoralis minor.	Pectoralis major, acromion, deltoid.	M. subclavius.	M. subscapularis.	Regio-dorsalis scapulæ.	M. serratus magnus.	M. latissimus dorsi.	M. teres major.	Posterior circumflex.	Anterior circumflex.	Axillary glands and fascia	M. coraco-brachialis.	M. biceps.	Articular	Posterior region of scapula	Superior profunda.	
1. Superior thoracic	3			3	1						4	3	1													Absent once, supplied by acromio-thoracic (see line 2).
2. Acromio-thoracic		4		1	4	4	1		4	3																
3. Subscapular			4			3	4	4					4	4	4	4	3	1	1	1						For 3 remaining cases, see lines 3 and 6.
4. Anterior circumflex			1																1							
5. Posterior circumflex			1															1								See lines 3 and 6.
6. Circumflex trunk			2															2	2							See lines 3, 4 and 5.
7. M. subscapularis	2	1											3													
8. M. coraco-brachialis			3																	3						No branch from axillary, supplied by brachial in 1 case.
9. M. biceps			3																		3					Same.
10. M. pectoralis minor		2								2																
11. Axillary glands, etc			1																	1						Represented by a definite branch twice (see line 3 for 1 case) remainder supplied by various arteries.
12. Posterior scapular	1																							1		See text.
13. Superior profunda			1																						1	See text.

TYPE V, 3 CASES.

1. Superior thoracic	2			2	1																				See line 4.
2. Acromio-thoracic		1							1	1	1	1	1												See line 4.
3. Subscapular		1			1	1	1	1	2	1			1	1	1	1									See lines 2 and 3.
4. Common trunk		2		1	2	2	2	2		2	2	2	2	2	2	2	2	1	1	1					
5. Anterior circumflex																									
6. Posterior circumflex																									
7. Trunk, common to anterior and posterior circumflex			3															2	2						

TYPE VI, 2 CASES.

1. Superior thoracic	2			2	1									2											
2. Acromio-thoracic	2				1				1	1	2	1								1					Pectoral branch absent in one case and small in the other. Supplied by pectoral branch (line 8)
3. Long thoracic	2				2	2	2			2				2											
4. Subscapular			2				1	2					2	2	2	2				1					Teres major supplied by dorsalis scapulæ, getting no branches from subscapular direct.
5. Anterior circumflex			1																1						See line 7 for remaining origin.
6. Posterior circumflex			1															1							See line 7.
7. Trunk, common to anterior and posterior circumflex			1															1	1						See lines 5 and 6.
8. Pectoral branch	2			2	2	1	1		1	2				1											See line 2.
9. Articular			1																						
10. Coraco-brachialis			1																						
11. Biceps			1																						
12. Clavicular	1											1													See line 2 for remaining case.

TYPE VII, 2 CASES.

1. Superior thoracic	1			1										1											See lines 3 and 8.
2. Acromio-thoracic	2								1	1	2	2													Pectoral branch absent in 1 case (see line 8), supplied by pectoral branch and by subscapular (see line 3).
3. Subscapular	2			1	1	1	2	2	1	1			2	2	2	2	2			1					
4. Circumflex trunk			1															1	1						For remaining case see line 5.
5. Trunk			1															1	1		1	1		1	See line 4.
6. Posterior scapular	1																						1		
7. Pectoralis minor		1								1															
8. Pectoral branch	1			1	1	1	1		1	1			1		1										See line 2. Supplies pectoral area of acromio-thoracic
9. Axillary glands and fascia			1																	1					Was present as a rather large artery both in this case and in that from the subscapular (see line 3).

ON THE ORIGIN OF THE LYMPHATICS IN THE LIVER.

By Franklin P. Mall,

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The origin of the lymphatics of the liver was first definitely determined by MacGillavry,[1] who studied this subject under the direction of Ludwig. Long before the work of MacGillavry it had been observed that ligature of the bile duct was followed by passage of bile over into the lymphatics, and the artificial filling of the lymphatics naturally followed by injecting a colored fluid into the bile duct. Sections of liver, in which the lymphatics had been filled with Prussian blue, or with asphalt, showed that the fluid injected into the bile ducts leaves them at the periphery of the lobule to enter spaces surrounding the blood capillaries, the so-called perivascular lymph spaces. These spaces communicate at the periphery of the lobule directly with the interlobular lymph channels. Frequently there is an extravasation of the injection mass into the blood capillaries of the lobule.

These observations were subsequently confirmed by numerous competent investigators, using the method employed by MacGillavry as well as that of direct injection of Prussian blue into the walls of the portal and hepatic veins. In successful injections made in this way it is found that the Prussian blue injected enters the lobule to encircle its blood capillaries.[2] Such injections, however, are always accompanied with numerous extravasations of the injected material into the tissues between the lobules, and often there is a secondary injection into the blood capillaries of the lobule. This fact has raised an objection to the direct injection of the lymphatics from the bile capillaries. It appears more probable, the opponents say, that the extravasation of bile, or the injected material into the interlobular spaces, enters the lymphatic radicals of the capsule of Glisson, and from them the larger lymph channels and the perivascular spaces of the capillaries are filled. Furthermore the injected mass may pass from the pericapillary spaces directly into the capillaries, thus accounting for their frequent injection.

According to Fleischl,[3] all the bile is taken up by the lymphatics after ligature of the bile duct, and in case the thoracic duct is also ligated no bile or only a trace of bile ever reaches the blood. The observation of Fleischl has been confirmed by Kunkel,[4] Kufferath [5] and Harley.[6] It is extremely difficult to understand why the bile does not enter the blood capillaries in case it passes from the bile capillaries over into the perivascular spaces before it reaches the interlobular spaces after ligature of the bile duct. A further objection to the idea that the perivascular spaces first take up the bile, after ligature of the duct, is the fact that fluids injected into the bile duct pass with ease over into the lymphatics but only with difficulty into the bile capillaries. In all cases it appears as if the main origin of the lymphatics is at the periphery of the lobule and that the radicals communicate freely with the perivascular lymph spaces. Furthermore, it appears that the course the bile takes after ligature of the bile duct, or of a fluid injected into the bile duct in passing to the lymphatics, is between the lobules or at least at their extreme periphery. This idea is greatly strengthened since we know that the walls of the capillaries of the lobule are extremely porous, being composed of a dense layer of reticulum fibrils[7] upon which lie the endothelial or Kupffer's cells. This layer of reticulum fibrils encircling each capillary has been described from time to time by many investigators, and has been isolated by Oppel[8] and by myself.[9] Oppel obtained clear pictures of the connective tissue of the liver lobule by means of silver precipitation, while I employed Kühne's method of pancreatic digestion to remove the cells, followed by some intense stain like acid fuchsin. The nature of these fibrils is still under discussion but that matters little for the present communication. It is sufficient to know that the fibrils of reticulum form a basket-like membrane surrounding each capillary of the whole lobule, the interior of which is only partly lined by Kupffer's syncytial endothelial cells. The capillary walls then are very pervious, blood plasma passing easily from them out into the perivascular spaces to bathe the liver cells.

It is well known that a large quantity of lymph is constantly passing from the liver, much more than from any other organ. That this lymph comes directly from the blood is indicated by its high per cent of proteid matter, nearly that of the blood, and from two to three times that of the lymph from other parts of the body.

The course the lymph takes from the blood to the lymph radicals, *i. e.* its natural course, can easily be marked by injecting colored gelatin into any of the blood-vessels. I have usually found it most convenient to inject the gelatin into the portal vein, but it is just as easy to fill the lymphatics by injecting either the hepatic artery or hepatic vein. In all cases the colored fluid reaches the main lymph channels in the same way. The colored gelatin flows with great ease from the capillaries at the periphery of the lobule as well as from those around the sublobular vein into the lymphatics. After the lymphatics have all been filled it is well to inject a small quantity of fluid of different color into the blood-vessels. A much better method of making double injections is to mix red granules with a blue gelatin or blue granules

[1] MacGillavry, Wiener Sitzungsber., 1864.
[2] Budge, Ludwig's Arbeiten, 1875.
[3] Fleischl, Ludwig's Arbeiten, 1874.
[4] Kunkel, Ludwig's Arbeiten, 1875.
[5] Kufferath, Arch. für Physiol., 1880.
[6] Harley, Archiv für Physiol., 1893.
[7] Kupffer, Arch. f. Mik. Anat., 54.
[8] Oppel, Arch. Anz., 1890.
[9] Mall, Abhandl. d. K. S. Ges. d. Wiss., xvii, 1891.

with a red gelatin, the fenestrated lining membrane of the capillary acting is a sieve which allows the fluid to pass but holds back the granules, as is the case with the blood when normal circulation is taking place.

If the portal vein is injected with Prussian-blue gelatin under a low pressure, it is found that in a few minutes the lymphatics are all filled with the blue mass. Livers injected in this way are best hardened in formalin and then cut by the freezing method, for alcohol causes the gelatin to shrink. Such sections show that the blue fluid has entered the lymphatics at the periphery of the lobule. More instructive are the specimens when the injection is stopped just as the first lymphatics are filled with the colored gelatin. By following the larger lymphatics back into the liver substance it is found that the interlobular connective tissue is entirely filled with blue where the lymphatics are injected, but only partly colored blue when they are not. In other words, the blue extravasates from the periphery of the lobule, invades the connective tissue until it reaches the beginning of the lymphatics, when of course it is carried rapidly from the liver. The nearest course from the lobules to the lymphatics is between the lobule where the amount of connective tissue is small, so when colored fluid is beginning to enter lymph channels the tips of the capsule of Glisson are entirely colored, while larger portal spaces are encircled by a zone of the color. Furthermore it is found that in certain instances when the injection was not continued long enough the blue did not enter the lymphatics. In such specimens it is found that all the interlobular spaces are surrounded by a zone of colored gelatin which does not enter the main lymph channels.

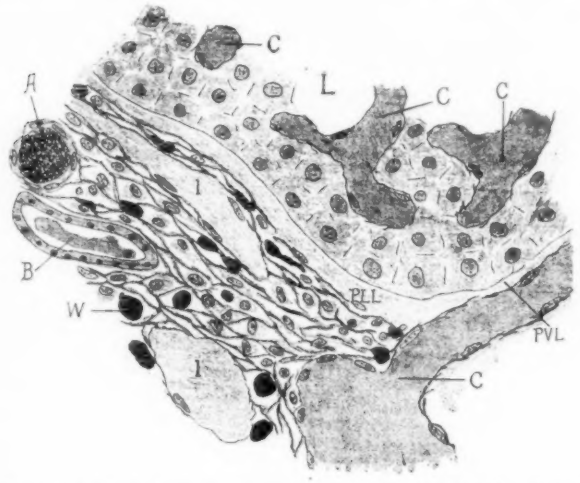

Fig. 1.—Section through the periphery of the liver lobule of a cat. The hepatic artery was injected with cinnabar gelatin, and the portal vein with Prussian-blue gelatin, stained with Van Gieson's stain. ×500 *L*, lobule of liver; *c*, capillaries; *a*, artery; *l*, lymph vessel; *prl*, times. perivascular lymph space; *pll*, perilobular lymph space; *w*, bundles of fibrils of white fibrous tissue.

A successful injection of the lymphatics is illustrated in the accompanying figure. The section was stained with Van Gieson's stain which gives a very satisfactory result. The granular blue enters the capillaries of the lobule, *c*, with ease, and from them the liquid blue is filtered through the capillary walls to enter the perivascular lymph space. This space communicates at the periphery of the lobule directly with a large lymph space between the liver cells and the capsule of Glisson, which I shall term the perilobular lymph space. These spaces in turn communicate with the lymph radicals.

Injection of the blood-vessels of the liver with aqueous Prussian blue fills the capillaries only, and in all cases it is shown that there are no capillaries between the periphery of the lobule and the interlobular connective tissue. The liver cells come directly against the capsule of Glisson. An injection of brief duration with blue gelatin soon fills the perilobular lymph spaces, so that it appears as if all groups of liver cells at the periphery of the lobule were separated from the interlobular connective tissue with capillaries. In case cinnabar granules are mixed with the blue a few of these granules are found in the perivascular and perilobular lymph spaces. The openings in the walls of the capillaries are large enough to allow a few of the smaller granules to pass through. As the injection is continued the blue invades the connective tissue spaces from the lymphatic radicals more and more until a lymph channel is reached, when of course it flows rapidly from the liver. Were there a direct channel from the perilobular lymph spaces the blue should flow through it at once without further filtration through the interlobular connective tissue spaces. The course the cinnabar granules take also speaks against a direct channel between the perilobular lymph spaces and the interlobular lymph channels. A few of the granules enter the perilobular lymph spaces, but none of them reach the main lymph channels. All of my specimens without exception force me to the conclusion that there are no direct channels connecting the perivascular and perilobular lymph spaces with the lymphatics proper other than the ordinary spaces between the connective-tissue fibrils of the capsule of Glisson. These spaces, however, are relatively large, permitting of a rapid diffusion through them.

Interstitial injections into the walls of the interlobular veins naturally fill the surrounding lymphatic vessels, and when no valves are in the way the injected fluid passes to the origin of the vessels, or lacunæ, which are only in part lined with endothelial cells. From here the fluid passes through the main connective-tissue spaces to the periphery of the lobule into the perilobular and perivascular lymph spaces, and frequently from them into the blood capillaries. When the injection is made through the bile ducts I have always found that there is an extravasation of the fluid from these at the periphery of the lobule which immediately enters the lymph radicals, although the bile capillaries are often injected well into the lobule. The extravasation does not take place from the bile capillaries, only from the duct as it communicates with the capillaries; also it does not take place from the larger bile ducts. Such extravasations naturally are picked up by the lymphatics and are at once carried from the liver. If after ligature of the bile duct the bile enters the perivascular lymph space within the lobule it may still be carried to the

lymphatics, as the direction of the current of lymph is constantly from the blood capillaries to the lymphatics.

It is well known that the liver cells arise from the embryonic bile ducts, and that in the further growth of the liver the bile ducts must elongate in order to adjust themselves with the growing liver. Hendrickson [10] has shown by staining the bile capillaries and ducts of the embryo's liver by Golgi's method that the tip of the primitive bile duct is added to by a coalescence of the bile capillaries at the periphery of the embryonic liver lobule. My own observation on the liver lobule after it is well formed is that whenever karyokinetic cell figures are present they are at the periphery of the liver lobule, *i. e.* at the junction of the bile capillary with the bile duct. It also appears that the vascular walls of the embryo are much more pervious than those of the adult, judging by the ease extravasation takes place when the blood-vessels of embryos are injected. This observation taken with that of the growth of the bile ducts may be an explanation why the extravasation of a fluid injected into the bile duct takes place at the periphery of the lobule. A further hint in this direction is the observation that it is easy to inject the lymphatics from the blood-vessels of an inflamed area. I have often seen the lymphatics of an inflamed intestine filled with blood, and upon injecting the blood-vessels found that the fluid readily entered the lymphatics."

[10] Hendrickson, Johns Hopkins Hospital Bulletin, 1898.

[11] See also Sigmund Mayer, Anat. Anz., 1899.

That the capillaries of the liver communicate more freely with the lymphatics than do the bile ducts is proved by injecting the bile duct and the portal vein with fluids of different color under the same pressure at the same time. In all the experiments I made the fluid injected into the vein appeared in the lymphatics first. In many instances beautiful injections of the lymphatics were obtained from the vein while the fluid injected into the bile duct did not extravasate at all, showing at least that the veins communicate with the lymphatics much more freely than do the bile ducts.

The conclusions to be drawn from the above observations are (1) that the lymphatics of the liver arise from the perilobular lymph spaces and that these communicate directly with the perivascular lymph spaces; and (2) that the lymph reaches these spaces by a process of filtration through openings which are normally present in the capillary walls of the liver. Furthermore, the fluid injected into the lymphatics from the bile duct leaves the duct as it enters the lobule and is at once taken up by the lymph radicals and perilobular lymph spaces, and from them extends, as a secondary injection, to the perivascular lymph spaces, and often into the blood capillaries of the lobule. The larger lymphatics accompanying the portal vein arise between the lobules near their bases, while those accompanying the hepatic vein do not arise within the lobule but around the larger sublobular veins.

BORN'S METHOD OF RECONSTRUCTION BY MEANS OF WAX PLATES AS USED IN THE ANATOMICAL LABORATORY OF THE JOHNS HOPKINS UNIVERSITY.

By Charles Russell Bardeen,

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The wax-plate method of reconstruction (Plattenmodellen methode) described by Born in 1876 [1] has proved of great value in the study of the morphology of embryos. The method has received its most extensive application in the hands of Born, of His and of various pupils of these investigators. In general, however, it may be said, that the value of this method as an aid to the microscopic study of form has not been sufficiently appreciated.

In part this lack of a more general application of the method has been due to certain technical difficulties which tend to make it cumbersome and time-consuming. Yet by no other method can so accurate an idea be obtained of the form of those structures which from their minuteness or complexity of relation cannot well be dissected out.

Considerable application of the method has recently been made by different persons in this institution and each worker has contributed something towards making the method more effective.

[1] Morph. Jahrb. II; Arch. f. mikr. Anat., xxii, p. 584.

As originally described by Born several steps are essential for the successful application of his method. These may be tabulated as follows:

A. Preliminary steps.

1. Obtaining a good picture of the embryo or object to be reconstructed.

2. Hardening, staining and sectioning the object.

3. Drawing magnified enlargements of the sections or such parts of them as it is desired to reconstruct.

4. Preparation of the wax plates.

5. Transference of the image to the surface of the wax and cutting out the wax plates.

B. Constructing the model.

1. Piling the wax plates.

2. Removing parts not essential to the reconstruction desired and rounding off of the parts reconstructed.

3. Strengthening and finishing the model.

I shall consider these steps in the order named.

A. Preliminary steps.

1. Before proceeding to section the object to be recon-

structed it is important to obtain good pictures of its external form. With such a picture at hand it is much easier to pile up the wax plates which represent the sections through the object. This is especially true when the object is symmetrical, as in the reconstruction of embryos, profile views of which are invaluable in this work. If the picture be enlarged to the magnification of the model desired a valuable control is furnished. A series of parallel lines may then be drawn through the picture to represent the planes through which the knife has passed in sectioning the embryo, so that the position of every plate is indicated.

For general purposes photography is undoubtedly the most convenient method of recording the gross external features of the object. If the object be very small as, for instance, an early human embryo, the camera may be so placed that the image in the negative is enlarged from two to four diameters. It is found that the most convenient way of photographing embryos is to place the camera with the axis in a vertical direction and the lens pointing downwards. A stand for holding the camera in this position and raising or lowering it is easily constructed. Ordinary lead shot seems to be especially good for holding many small objects in the position in which it is desired to photograph them.

For detail in the distant as well as the proximal part of the object it is a great aid to make use of a stand capable of being raised without moving the object laterally. In this way, if the diaphragm be closed down so as to make the exposure a long one, the object may from time to time be brought slightly nearer to the lens of the camera, so that parts more distant are brought into sharp focus.

From the photographic plates thus obtained lantern slides are made or the negative itself is used to project the image at the required magnification upon a screen. Free-hand drawings are then traced on a paper upon which the image falls, or, if desired, bromide enlargements can be made. In this way accurate records can quickly be made of the external appearance of the object to be studied, yet no special talent for drawing is required. In the study of embryos the profile view is the most essential one, though others also prove of great value.

2. The only real essentials in the technique of obtaining serial sections of the object to be studied are that the series should be complete, the sections perfect and of uniform thickness. As pointed out by Born, the most convenient sections for this work are those from 20-40 microns in thickness. For sections of this thickness we have found alum cochineal to give uniformly the most satisfactory stain. It is important to know which side of the sections was uppermost during the cutting, so that in the subsequent reconstruction a true and not a mirror image of the object will be formed. For this reason it is well to make it a uniform practice to begin at the head when cutting transverse sections through an embryo, at the right side when cutting longitudinal vertical sections, and at the dorsal side when cutting horizontal sections and to label the sections in the order in which they have been cut.

3. For making drawings of the sections we have found that in general a projection apparatus is more convenient than a camera lucida unless the sections are small. Our projection apparatus is set up in a large dark room.

The illumination is received from an arc electric light or from a heliostat. An ordinary microscopic stand with the tube in a horizontal direction is used when the sections are small and a high magnification is desired. Eye piece and draw tube are usually removed and the objective is used as the magnifying lens. In case of larger sections a projection lens similar to that used for lantern slides is utilized.

The image is projected upon a screen which runs on a track. The screen can be moved toward or away from the microscope by means of windlass situated near by. In this way any desired magnification can be quickly obtained by using an appropriate lens and bringing the screen into the proper position.

The screen which I devised for our dark room has attached a leaf which can be lowered so as to form a drawing table and a mirror that can be placed at an angle of 45° over the table. In this way the image is projected on a horizontal surface so that tracing it is easier than when it is upon a vertical surface. In using an ordinary mirror a double image is projected but that from the surface of the mercury is so much brighter than that from the surface of the glass that no difficulty is experienced in drawing accurate outlines.

Fig. 1 illustrates the apparatus here in use.

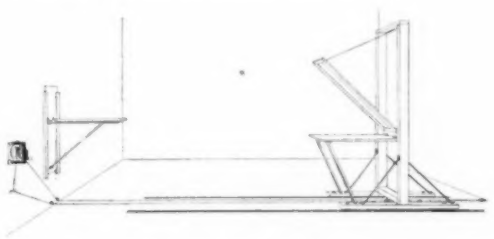

FIG. 1.—At the right the projection screen is shown in position on the track. The mirror is lowered to an angle of 45° and the drawing table is extended horizontally below this. At the left are shown the windlass used for moving the projection screen and the shelf used for holding the projection lantern.

In drawing pictures of the sections a careful outline of those main features which it is desired to bring out in the reconstruction is the great essential. In addition it is often of value to distinguish by using pencils of various colors the different organs in structures as they appear in the section.

If desired, direct bromide enlargements can be made of the sections on the slides. This is the method preferred by His. The simpler method described above we have found, however, to be more convenient for general purposes.

The outline drawings may often be elaborated to any desired extent when the sections are subjected to careful microscopic study. It is a great help for the subsequent reconstruction to label, so far as possible, the various structures in the outlines of the sections before proceeding to the wax plates.

1. Much trouble in the preparation of the wax plates is to be saved by using plates of a uniform thickness and by making the magnification of the object under reconstruction correspond. The most convenient thickness for general use is 2 mm. Occasionally, for coarser work, 4 mm. plates have proved of value. It is very easy, with the apparatus above described, to make the ratio of the diameter of magnification of the drawings to the diameter of the sections equal to that of two millimetres to the thickness of the section. If plates 2 mm. thick be used and every section be drawn, sections 20 mm. thick = 1/50 mm. must be magnified one hundred times. Or if desired, as is more often the case, every other section may be drawn at a magnification of fifty diameters.

For making the wax plates we have a large zinc pan with vertical sides. Its surface area is such that one kilogram of the wax mixture which we use will make a plate 1 mm. thick. The method of casting the plates is essentially that described by Born. Boiling water is run into the pan to the depth of several inches. On the surface of this the hot melted wax mixture is poured and quickly forms an even, smooth layer. Bubbles, which occasionally appear in the wax, may be quickly exploded by turning the flame of a Bunsen burner on the surface of the wax where they appear. As the wax plate cools it is necessary to free it from the sides of the pan by running a knife along the edge. Before the plates are perfectly cool they may readily be cut into smaller plates of any desired size.

The wax mixture in use here is composed of 950 parts of bees-wax and 50 parts of white rosin. Often, especially in summer, paraffin is added to give additional toughness. Black plates are made by adding lamp black to the melted wax, until after thorough stirring the mixture has become uniformly black. The amount by weight of wax necessary for a plate of a given size is obtained more easily by experimental trial than by calculation. A certain amount of wax becomes attached to the sides of the pan by surface tension, so that slightly more wax must be used than the amount one is likely to determine by calculation from the specific gravity of the wax and the size of the pan. On the other hand if a pan of a given size be used the amount of a given wax mixture necessary for making a plate of given thickness may be determined by a few trial castings.

The outlines are transferred to wax by means of red or blue tracing paper. The wax plates are then placed upon glass and are cut with a small, narrow knife and in a warm room.

B. Constructing the model.

1. The janitor can be trusted to trace the outline drawings on wax, to cut through the wax with a sharp knife where the outlines are traced and to make the preliminary piling. Usually two preliminary piles are made, one of that part of the wax plates which represent the sections and one of the wax plates themselves after removal of the parts representing the sections. From the former a positive, from the latter a hollow negative image of the original object is obtained. In this piling an enlarged picture of the object is of very great help. As originally suggested by Born, in case of symmetrical objects a surface outline may be drawn on card board and cut out, thus giving a fixed ridge against which to pile the plates. If but one side of any embryo is to be reconstructed from transverse sections it is of great help to cut each plate off sharply at the midline and to pile the plates against a profile outline of the embryo situated on a board which has been placed perpendicular to the plane in which the plates are piled. In case the reconstruction of some internal organ is wanted it is usually of advantage to reconstruct at the same time the external form of the object, so that when the plates are piled the image they form may be compared with the picture of the original object. After getting the plates composing the positive image of the object into proper position, it is easy to trace two or three of its surface curves on paper or to represent them in wire and then to get the negative formed, as described above, into true shape. Plaster casts can then be made in this negative mould. The plaster casts, representing the external features of the original object, are very valuable to have at hand, while engaged in reconstructing the internal features from the wax plates.[2]

The method of making every fifth plate a black one has proved to be extremely valuable in arranging the wax plates. In this way it is easy at any time during the reconstruction of the model to count up and place any given section.

The method of reconstruction which I have found most convenient is as follows: After the plates are placed in proper position so that the external features of the object are accurately portrayed, I begin by taking off five plates from one side. The drawings of the sections I likewise have pinned together in groups of five in the same order in which the plates are piled. By going over the five finished drawings it is easy to obtain a good conception of the form of the structures represented in the block of five plates under consideration. I have at hand a paper of fine pins and these I press down through the various structures seen in section on the surface plate, and in such a direction that they will pass into the same structure in the sections below. When the parts of the plates which represent the structures to be reconstructed are thus firmly united by pins I remove the intervening portions of the wax plate with a pair of forceps. Thus, in a very short time, one is enabled to bring to light the form of the structures lying within the block of five sections. The pins hold the various bits of wax firmly in place and serve to strengthen the model in every way. When I feel satisfied with the appearance of the structures in the first block of five sections I proceed to the next and treat it in the same way. Those structures which are cut in both blocks of sections may at the same time be pinned together. After two or three blocks of sections have thus been piled up it is often well before adding another block of five sec-

[2] Many methods have been devised of piling plates according to special marks. The method devised by Wilson, Zeitschrift für wissenshaftliche Mikroscopie, xvii, 1900, page 177, seems a good one.

tions to fuse them together with a hot knife and thoroughly to strengthen the reconstruction so far as it is completed. For strengthening piles of narrow strips of wax, representing sections through membranes and the like, a wire netting is of the greatest value. Perhaps the best form of wire netting for general purposes is a copper netting with 10 strands to the centimetre. The copper netting has no tendency to cause subsequent warping, as is the case with iron netting. The netting is heated in the flame of a Bunsen burner and is then applied to the surface which it is desired to strengthen. In case of narrow columns, such, for instance, as are formed in the reconstruction of blood-vessels and nerves, copper wire is of the greatest value. This can be heated and sunk in at one side and then fused over.

After the model is once well started the subsequent building up can proceed with great rapidity. Plates in blocks of five are added as described above until the model is finished. Of course a greater or less number of plates than five may be used to a block. In most of my work, however, I have found blocks of five, with a black plate on the surface of each block, to give the most satisfactory results.

In order to keep the various structures distinct during the reconstruction it is often of value to paint them with different colors, while the work proceeds. The various structures of a model built up as described may be removed as completed, or during the course of reconstruction, and then readily replaced. Pins are of great value in holding structures in place and for indicating where a structure removed must be replaced in order to regain its proper position.

If it is desired at any time to cut the model in a given direction the pins which hold the pieces of wax together may be readily cut with scissors.

3. I have mentioned methods by which the model is greatly strengthened during the course of reconstruction, the use of pins, of wire netting and of wire. All three means may be employed thoroughly to strengthen the model after the first rough reconstruction. The wire screening is then especially valuable. Of course it is possible to add free hand and with a good deal of accuracy structures which from their delicacy are difficult to model. This is true of blood-vessels, nerves and of fine membranes. The blood-vessels and nerves may be readily constructed by covering copper wire with wax, the membranes by covering a netting of narrow meshes with a thin coating of wax.

In rounding and smoothing up various structures in a model so as to give it a finished appearance, semi-melted wax applied with the fingers or with a spatula is of the greatest help.

The model is greatly protected in many ways by a thick coating of paint. Hot weather seems to have a far less detrimental effect on such models than on models unpainted.

We have found photography of great help not only in recording the condition of the finished model but also, at times, during the course of a reconstruction.

MODEL OF THE NUCLEUS DENTATUS OF THE CEREBELLUM AND ITS ACCESSORY NUCLEI.

By Harry A. Fowler.

(From the Anatomical Laboratory of the Johns Hopkins University.)

At the suggestion of Dr. Barker I have undertaken the study of the central gray matter of the cerebellum and its relations to the white fibre bundles to which it is intimately related. It has seemed advisable to make a partial report including a reconstruction in wax of the nucleus dentatus and its accessory nuclei.

In a study of the internal structure of the cerebellum it is necessary to consider the work of Stilling on this region. To him belongs the credit of being the first to study the internal anatomy of the cerebellum by means of serial sections made in various planes and stained with dyes to bring into greater contrast the white matter and the gray masses. With the crude methods at his disposal for preparing serial sections and staining them, the drawings of Stilling show with remarkable accuracy the relations of these central nuclei to the white substance in which they lie buried and to which they are closely related.

The Material.—The model was made from a series of transverse sections through the medulla and cerebellum of a new-born babe prepared by Dr. John Hewetson in the Anatomical Laboratory of the University of Leipzig. The material was hardened in Müller's fluid, cut 70μ thick, and stained by the Weigert-Pal method. Every other section was used and hence each section represents a thickness of 140 microns. A series of sagittal sections through the medulla and cerebellum of a new-born babe was also prepared and treated in a similar way for use as a control in measurements and to furnish an outline of the floor of the fourth ventricle. This outline was used in building up the model.

The Method.—Born's method for making wax plates as carried out in this laboratory has been fully described by Dr. Florence R. Sabin.[1] A magnification of twenty diameters was decided upon, because (1) it gives a plate of convenient size to work with so that the numerous foldings of the surface of the dentate nucleus can be distinctly outlined, and (2) the thickness of the plates—2.8 mm.—makes them easy to cut and convenient to handle—two points of considerable practical value. Outline drawings were made first with a projection apparatus at a magnification of twenty diameters. These drawings were then controlled with a higher magnification before transferring them to wax plates.

In building the model a real difficulty presented itself—the

[1] Sabin, Contributions to the Science of Medicine, and Johns Hopkins Hospital Reports, ix.

difficulty of controlling the curves. Inasmuch as the central nuclei of the cerebellum lie deeply buried in the white matter of the hemispheres and worm one does not have the assistance afforded by external form in building up the model. In studying the sections it was noted that the dentate nucleus and accessory nuclei are bisymmetrical, and a prolongation of the raphe of the medulla dorsalwards bisected the cerebellum, passing through the middle point in the roof of the fourth ventricle. Corresponding points in the nuclei of the two hemispheres were equidistant from the median line so drawn and from the middle point in the floor of the fourth ventricle. In building the model these two guides were used: (1) the median line which controlled the lateral curve, and (2) the outline of the floor of the fourth ventricle which controlled the dorsoventral curve. In the sagittal series the section passing through this central point in the floor of the fourth ventricle was selected and an outline of the longitudinal curve of the floor was made. A flat surface having one straight edge was then obtained. This edge corresponded to the median line. To this edge was attached the outline of the floor of the fourth ventricle, already described, at the proper angle corresponding to the angle at which the sections were cut. With these two guides fixed the plate corresponding to the lowermost (distal) section, in which the dentate nucleus appeared, was placed at a proper distance from the median line, *i. e.* the edge of the board and the upright outline of the floor of the fourth ventricle, and fixed in place. The succeeding plates were piled with reference to these two guides and the plates already piled, and each plate as it was put in proper position was fused with the plates already fixed.

The outline of the nucleus dentatus is very definite and easily traced. The capsule or Vleiss (Stilling) on the outside and the cor? or Markkern on the inside are both medullated and take the stain, thus distinctly limiting the yellow mass of cells composing the nucleus. The drawings could be very accurately made. In attempting to outline the accessory nuclei, however, one meets with a real difficulty. This applies particularly to the nucleus globosus and the nucleus of the roof. The nucleus globosus instead of forming one mass of gray matter is made up of several irregular groups of cells separated by deeply stained medullated fibres belonging to the fibre systems of this region. These separate groups are clearly limited with a magnification of twenty diameters, but when studied under higher powers one finds cells evidently belonging to these groups scattered among the dense network of deeply stained fibres. In studying the nucleus globosus

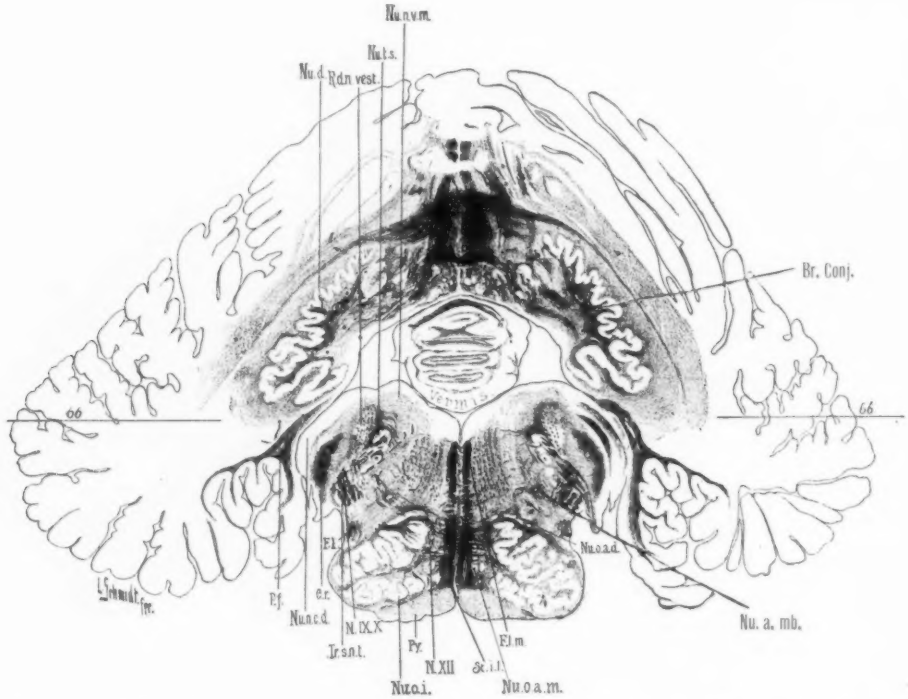

FIG. 1.—Transverse section of medulla and cerebellum (after Sabin, J. H. H. B., No. 81, December, 1897, Fig. 2.) Section at level of nucleus of glossopharyngeus and vagus nerves. Section also passes through upper part of the dentate nucleus and accessory nuclei. Long axis of nucleus is seen to form an acute angle, with the median line (formed by extension dorsally of the raphe bisecting the 4th ventricle and the cerebellum), with the angle opening toward the medulla. Dorsolateral surface of dentate nucleus is parallel to the surface of cerebellum. Corpus restiforme is seen to cover this surface. The accessory nuclei appear separated and broken up by the white medullated fibres. Variations in thickness and foldings of walls of the dentate nucleus also well shown. Hilus opens medial- and ventralwards.

through several consecutive sections under high powers one gets the impression that the separate groups seen with a magnification of twenty diameters really form one nucleus; that this large mass of cells is separated into groups by the white fibres plunging directly through the nucleus; and this impression is further strengthened by noting the cells scattered among the fibres, included as it were by the bands of white fibres.

In outlining the nucleus of the roof one meets with the same difficulty. In going over these two nuclei with a high power to correct the drawings for transference to wax I had to include the scattered cells referred to. I did this by making the nuclei solid, not attempting to indicate the space occupied by the fibres.

One other point is to be noted. The so-called accessory nuclei, *i. e.* N. emboliformis, N. globosus and nucleus of the roof, are usually described and figured as entirely separate and distinct cell-mass. In this series of sections of the newborn babe, with the exception of the N. emboliformis, it has been difficult, indeed impossible, at certain levels, to separate these nuclei. The N. emboliformis forms a perfectly definite cell-group, in the lower (distal) sections, appearing as a thin, tongue-like ribbon of cells almost entirely occluding the hilus of the corpus dentatum. Sections at the level of the middle of the nucleus show it changing its shape, suddenly becoming thicker and shorter, but clearly separated from the corpus dentatum on one side and the nucleus globosus on the other side by thin, deeply stained bands of white fibres. The nucleus globosus also appears as a definitely limited and separate group of cells in the lower (distal) sections, appearing in sections a little above the beginning of the hilus of the corpus dentatum as a small oval area of gray matter. At a higher (proximal) level this oval mass is divided, as already indicated. At the highest levels it is not to be separated from the nucleus of the roof.

Corpus Dentatum.—It is embedded in the cerebellar hemisphere "like a peach stone" (Stilling). The distal end lies more deeply buried in the white substance; the proximal end approaches closely to the roof of the fourth ventricle, from which it is separated by a thin ribbon of white substance. Horizontal sections of the nucleus, as pointed out by Obersteiner, do not show the greatest diameter of the nucleus. This appears in sagittal sections.

The dimensions of the model of dentate nucleus are as follows:

1. Proximo-distal (sagittal), 19.8 cm.

2. Mesolateral, (in axis of nucleus and not at right angles to median line), 19.4 cm.

3. Dorsolateral, (perpendicular to mesolateral axis), 7.8 cm.

Remembering that the longest mesolateral diameter forms an acute angle with the median line with the angle opening ventralwards one will understand the measurements given.

The nucleus dentatus is really a hollow shell or sac with its long axis directed antero-posteriorly (proximo-distally). This shell is flattened dorsoventrally or at right angles to its mesolateral diameter. The walls, which vary in thickness from 0.3 to 0.5 mm., are thrown into numerous folds also varying in number and size in different parts of the nucleus. The folding of the walls gives to the surface an appearance not unlike the surface of the cerebral hemispheres or to the gyri and sulci of the inferior olive. The shell of gray matter is not closed but freely opens above (proximally), while the ventral and mesial walls are incomplete in the anterior (proximal) two-thirds of the nucleus. This opening in the walls forming the so-called hilus—hilus corporis dentati—looks median-, ventral- and cerebralwards. In the distal one-third of the nucleus the walls are complete and in transverse sections appear as oval closed rings or ring of gray matter.

The hilus in the more distal sections opens directly medianwards; in sections at a higher level (cerebralwards) the opening increases rapidly in size, the ventral wall becoming less complete, while the dorsal wall forms a complete covering. As a result of this progressive shortening of the ventromesial wall the hilus comes to open wider and wider ventralwards. This direction is further emphasized by the relation of the nucleus emboliformis. In the most distal sections lying within the mouth of the hilus it is in very close relation with the dorsolateral border, indeed in the distal sections it may be considered as a continuation of the dorsolateral surface on to the mesial surface, being separated by a very thin band of white fibres. This relation continues throughout the entire length of the nucleus, there being only a thin space of separation through which pass the most dorsal fibres escaping from the Markkern of the nucleus dentatus.

In addition, the dentate nucleus presents for description two surfaces, (1) dorsolateral, and (2) ventromesial; and four borders, (1) mesial, (2) lateral, (3) proximal, and (4) distal.

Dorsolateral Surface.—This is the largest surface of the nucleus (Fig. 2). It is irregularly quadrilateral in shape and lies parallel to the surface of the cerebellar hemisphere. The lateral and antero-posterior (proximo-distal) curves are slight, the surface being quite flat. In this connection it is interesting to note that a portion of the corpus restiforme lies over this surface of the nucleus, forming a shell enclosing the dorsolateral surface. This surface terminates mesially by a sharp thin border in its upper (proximal) two-thirds, by a rounded mesial border in its lower (distal) one-third. Laterally it is limited by the thicker, irregular and rounded lateral border. The proximal border also thin forms with the median line an obtuse angle opening spinalwards. The distal border is parallel to the proximal, is thick, rounded and is broken into by deep sulci. By reference to Fig. 2 it will be seen that the lowest sections of the nucleus includes only the mesial portion of this border.

The dorsolateral surface is traversed by five parallel deep fissures, which run parallel to the long axis of the nucleus. Beginning with median line these may be designated as *A*, *B*, *C*, *D* and *E*. These fissures divide the surface into six columns or gyri. Besides these five primary fissures there are five secondary sulci, which are shallower and incompletely divide the primary columns or gyri into secondary gyri. By reference to Fig. 2 the following points will be noted: Fissure

A is parallel to the mesial border, it is relatively deep and its corresponding gyrus on the inner surface of the nucleus looks lateralward (Fig. 3). The proximal end of fissure *A* curves laterally. Fissures *B* and *C* present three curves, the proximal and distal with convexities pointing mesially, the middle with convexity laterally. Fissure *C* is incomplete, its proximal end not reaching the proximal border. Fissures *D* and *E* form acute angles with fissure *C* with their proximal ends pointing obliquely medialwards. It will also be noted that the distal extremities of the columns or gyri are larger, thicker and divided by extension on to this surface of the fissures from the ventromesial surface. The deep fissures of the ventromesial surface alternate with the fissures on the dorsolateral surface. An exception to this is in fissure *D*, which is really an extension on to the dorsolateral surface of the lateral fissure of the ventromesial surface. There is no evidence of distinct lobulation visible on this surface.

The secondary sulci are limited chiefly to the three gyri nearest the median line. In other words, the folding of the dorsal wall of the nucleus is greatest nearer the mesial and proximal borders; it is thickest nearer the lateral and distal borders.

Ventrolateral Surface.—This surface is incomplete in its upper two-thirds. It differs markedly from the dorsolateral surface. It presents two deep fissures radiating from a point near the hilus about the level of the middle point of the nucleus. These fissures may be designated as (1) internal and (2) lateral. Within the internal fissure and nearly covered over by its projecting edges is a gyrus, broad at its base (distal end) and tapering above, becoming lost in the most proximal part of the fissure. This gyrus, partly concealed within the internal fissure, divides this fissure into two, both of which extend so as to appear on the dorsolateral surface. These two fissures, internal and lateral, of the ventromesial surface, divide this surface into three lobes, (1) internal, (2) median, and (3) lateral. The internal is the smallest and continues below the hilus on to the mesial border, being distinctly marked off from this border by a shallow sulcus. This lobe is broad at its proximal end, tapering off distally. The median lobe, broad at its base—distal end—narrows toward the point of divergence of the two fissures, internal and lateral. The internal and median lobes form the most distal part of the nucleus as viewed from its ventral aspect. They slope with a considerable curve to meet the almost perpendicular dorsolateral surface. They present no secondary sulci.

The lateral lobe is the largest. It forms the lateral border and extends on to both dorsolateral and ventromesial surfaces. On the former it lies lateral to fissure *E*, while on the latter it is limited mesially by the lateral fissure. This lobe is most irregular in outline, is broken up by numerous depressions and several secondary sulci. One of these sulci, more conspicuous than the others, runs parallel to the upper two-thirds of the lateral border.

The upper two-thirds of the ventromesial border is incomplete; the margin is very irregular as will best be understood by reference to Fig. 3. In general, it may be said that this surface, as compared with the dorsolateral, presents (1) deeper fissures, which give the appearance of lobulation, (2) thicker walls, and (3) fewer foldings of the walls.

The proximal end of the nucleus being open this border is limited to the thin edge of the dorsolateral surface, and the very small part of the ventromesial surface. This border slants obliquely spinal- and medianwards. The other borders have been referred to in describing the surfaces and the hilus.

The Accessory Nuclei.—The form and outline of the accessory nuclei, *i. e.* the nucleus emboliformis, nucleus globosus and nucleus of the roof, have been already referred to. Figs. 5, 6 and 7 show these nuclei in relation to the dentate nucleus. In Figs. 5 and 7 the nucleus emboliformis is seen as a long thin sheet of gray matter separated from the dorsolateral surface of the nucleus dentatus by a narrow space already described. Its most distal end nearly occludes the hilus corporis dentati (Fig. 7), while proximally it changes its form, becoming thicker and shorter, encroaching less on the hilus. It will also be noted (Fig. 5) that its axis changes; at first running dorsoventrally in its distal extremity, it comes to lie more laterally in its proximal part, corresponding in direction with the dorsolateral wall of the dentate nucleus. This nucleus is practically separate throughout its entire length, being the most definitely outlined of the accessory nuclei.

The nucleus globosus (Fig. 5) is also seen as a distinct oval mass of gray matter in its distal portion, beginning a little above the appearance of the hilus. In its proximal end this nucleus is represented as fused with the nucleus of the roof (Figs. 5 and 7).

The nucleus of the roof appears in the reconstruction as a large irregular mass, distinct in its distal portion, becoming fused with the nucleus globosus in its proximal portion. The outlines of this nucleus are indefinite in this series, its ventral surface being in very close relation with the gray matter of the roof of the fourth ventricle.

DESCRIPTION OF PLATES XXIX–XXX.

FIG. 2.—View of dorso-lateral surface of model of N. dentatus. Proximal end corresponds to top of figure; median line is to left. *M*, mesial border; *T*, lateral border; *A*, *B*, *C*, *D*, *E*, are placed over primary fissures; *a*, *b*, *c*, *d*, *e*, over secondary sulci; *f*, is extension on to dorsolateral surface of the internal fissure of the ventromesial surface.

FIG. 3.—View of ventromesial surface of model of N. dentatus. Median line to right. *I*, internal fissure; *L*, lateral fissure; *i*, internal lobe; *m*, median lobe; *l*, lateral lobe; *H*, hilus.

FIG. 4.—View of mesial border of same at right angles to median line. Relations of hilus to dorsolateral and ventromesial walls are shown. Distally the hilus is narrow, increasing rapidly as one passes cerebralwards.

FIG. 5.—View of mesial border of N. dentatus with accessory nuclei in place.

S, nucleus emboliformis; *G*, nucleus globosus; *R*, nucleus of the roof; *o*, narrow space through which escapes most dorsal fibres from Markkern.

FIG. 6.—View of dorsolateral surface of same. Legend as in Figs. 2 and 5.

Fig. 7.—View of ventromesial surface of same. Legend as in Figs. 3 and 5.

FIG. 2.

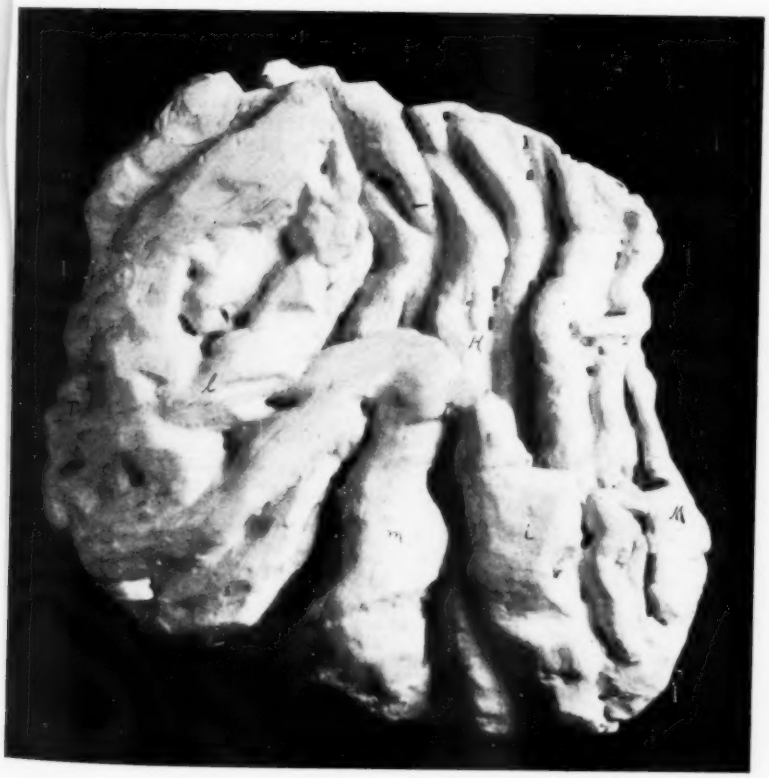

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 1.—The follicular artery and its capillaries. One of the long capillaries is seen to join a venous capillary in the periphery of the follicle; on either side of the follicle small veins are seen. Transverse sections of several veins are also seen.

Measurements: artery before dividing, 41 microns; and capillaries from 8 to 10 microns in diameter

FIG. 2.—The origin, course and distribution of a long follicular artery.

Measurements: at origin, 54 microns; and before dividing, 31 microns; capillaries in follicle, from 7 to 8 microns.

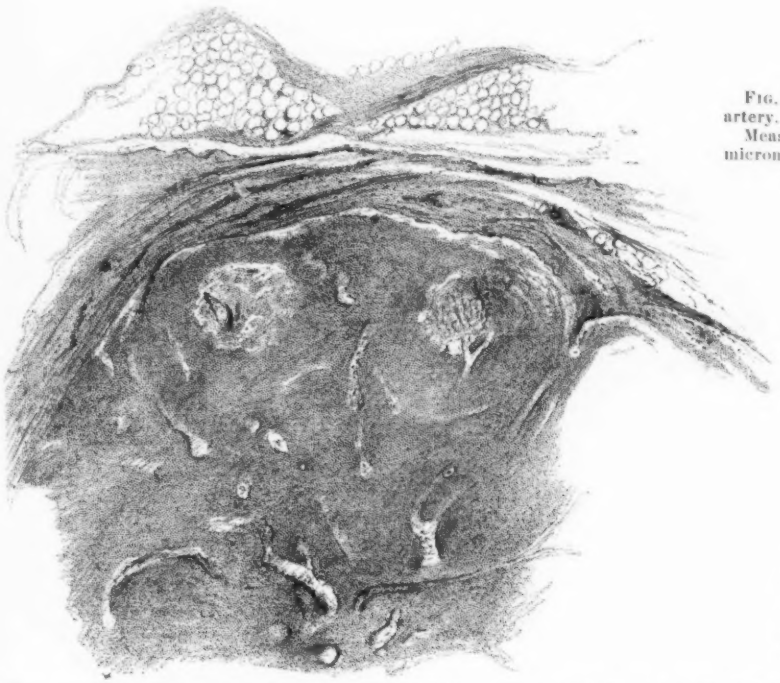

FIG. 5.—Two follicles with their veins. The follicle on the right shows a portion of a follicular artery entering the centre of the follicle. Below the proximal end of the follicle an artery is seen running parallel to the surface of the gland to turn toward the proximal end of the follicle; here it is lost.

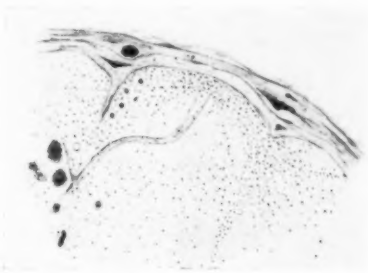

FIG. 3.—An artery arising some distance below the proximal end of a follicle, running toward the follicle to turn at a right angle and run to the centre of the proximal end of the follicle; here it again turns at a right angle to enter the follicle, where it divides in the usual manner.

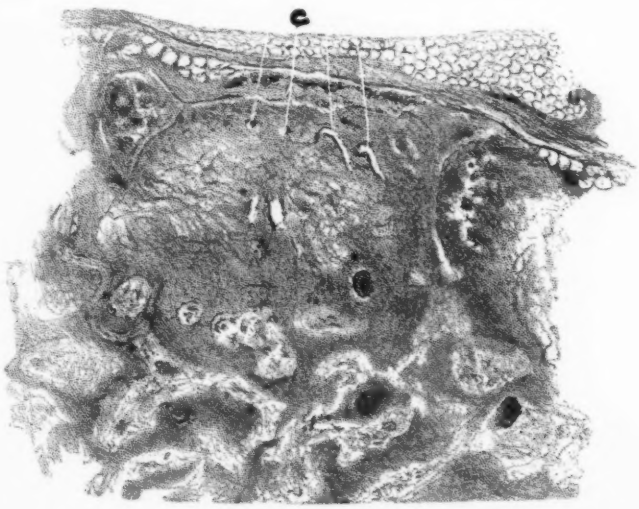

FIG. 6.—Long curved capillaries, *c*, near the periphery of the follicle.

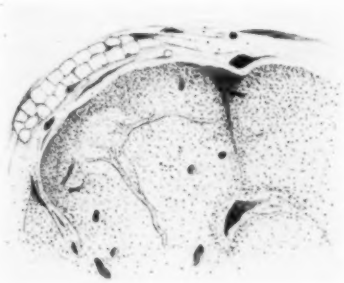

FIG. 4.—A double arterial supply to the follicle.

USE OF THE MATERIAL OF THE DISSECTING ROOM FOR SCIENTIFIC PURPOSES.

BY CHARLES RUSSELL BARDEEN, M. D.,
Associate in Anatomy, Johns Hopkins University.

Rosenberg, in a recent article,[1] has called attention to the opportunities that the dissecting room offers for scientific investigation. He gives an interesting summary of the various attempts that have been made to take advantage of these opportunities, and calls particular attention to the records obtained by Schwalbe at Strassburg, by Cunningham at Dublin, and by the Anatomical Society of Great Britain and Ireland.

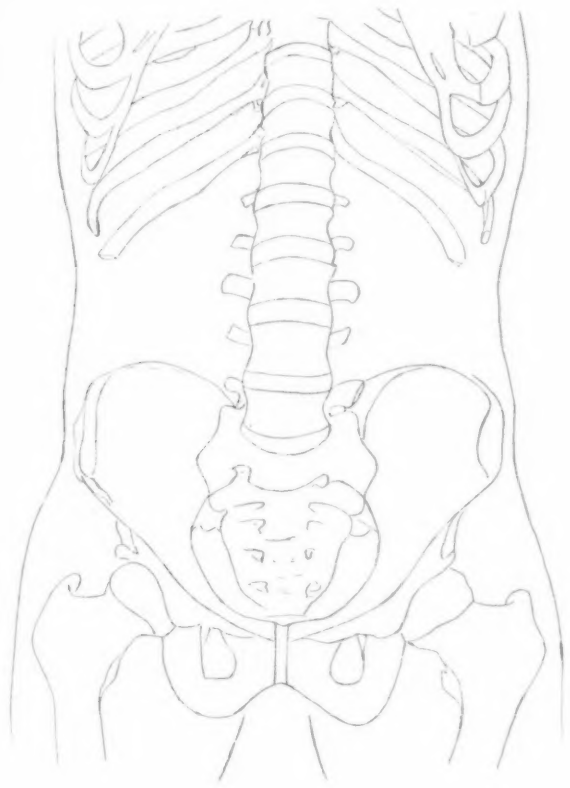

FIG. 1.

It has seemed to me that the methods employed to utilize the material of the dissecting room and the work of the students for scientific purposes in Professor Mall's laboratory at the Johns Hopkins University, Baltimore, may prove of interest, possibly of value, to those engaged elsewhere in anatomical instruction.

The immense amount of study that has been given to the structure of the human body during the last four centuries renders it unlikely that the student's untrained eye and hand could be utilized to advantage in a search for unrecorded facts of gross structure even if time permitted him to delve in those little nooks and corners where the records are still incomplete. The very considerable amount of variation, however, which the individual bodies present in the structure, form and relationships of their various organs, offers a rich field for cultivation.

Since the time of Darwin much attention has been given to the study of variations in plants and animals. The greater part of the attention, however, has been given to external features, to variation in size, color, and external form. Few studies have been made of the frequency of variation in the internal organs. Yet probably the body of no animal is more suited to this study than that of man and none is studied with care by so great a number of individuals each year.

Until comparatively recently the variations brought to light by the dissector have been recorded only when of an unusual nature. These observations, however, have been so numerous that we may assume that most of the variations likely to be brought to light have previously been recorded. While the limits of variation of the various organs of the body are thus fairly well understood, the frequency of variations has been determined but for few organs and for them only incompletely. The true "normal" or "most usual" is unknown. Henle, in his anatomy, pictured that as normal which his experience led him to think the most usual. Most of the other leading anatomists have done likewise. No two books, other than compilations from similar sources, give the same account of the normal form of the various organs. The great opportunity which the dissecting room offers is that of determining the curve of frequency of the various forms presented by bodily structures, and thus to make the normal a question of measurement rather than one of judgment. To render this possible, accurate records of the conditions found in each body must be made, of such a nature that they may be afterwards compared and reduced to tables.

The method of record thus becomes a question of paramount importance.

In the Anatomical Laboratory at the Johns Hopkins University the first attempts at making systematic records of conditions of structure revealed at the dissecting table were begun in the fall of 1895. It was determined to make a study of the variations in the distribution of the cranial and spinal nerves, especial attention being paid to the cervico-brachial and the lumbosacral plexuses. At the instigation of Professor Mall, Dr. A. W. Elting, at that time Assistant in Anatomy, prepared three record-charts, one for the nerves of the head, one for the nerves of the neck, arm and upper half of the thorax, and one for the lower half of the body. On these charts a record was made of the sex, color, and age

[1] Morphologisches Jahrbuch, 1895.

as well as of the nerve distribution in the body of the individual dissected. The scheme for recording the latter was as follows. On separate successive lines the numerical designation of a given cranial or spinal nerve was placed, followed by a list of the names of the nerves to which the given main nerve trunk was assumed to contribute. In the preparation of this table the standard anatomies were consulted. A few lines from the "Cervicobrachial Chart" may suffice to make clear the general nature of this scheme:

C. VI. Post-br. Ant-br.—Post-thoracic. Subclavius. Supra-scap. Com. **C. VII.**

C. VII. Post-br. Ant-br.—Ext-ant-thoracic. Com-post. cord. **Outer Cord.** Musc-cut.—*Cor-brach. Biceps. Br-ant. Ant. Post.* Outer-head-median.—*Ant-interos. Palm-cut. Thumb-br. 5 Digitals.*

C. VIII. Post-br. Ant-br. **Inner Cord. Post. Cord.** Sub-scaps.—*Upper. Middle. Lower.* Circumflex.—*Sup. Inf. Art.* Musc. Spiral.—*Musc. Int-cut. Ext-up-cut-br. Ext-low-cut-br. Musc.* Radial.—*Ext-br. Int-brs.* 4. Post-interos.—*Musc. Art.* Com. **D. I.**

The students were requested to compare carefully the nerves in the part dissected with the outline scheme, to underline the names of those nerves which were found to correspond with the scheme, to cross out the names of the nerves which did not thus correspond, and to insert these names in the proper place. Complex conditions, such for instance as are found in the cervicobrachial and the lumbo-sacral plexuses, were illustrated by diagrams drawn on the backs of the charts.

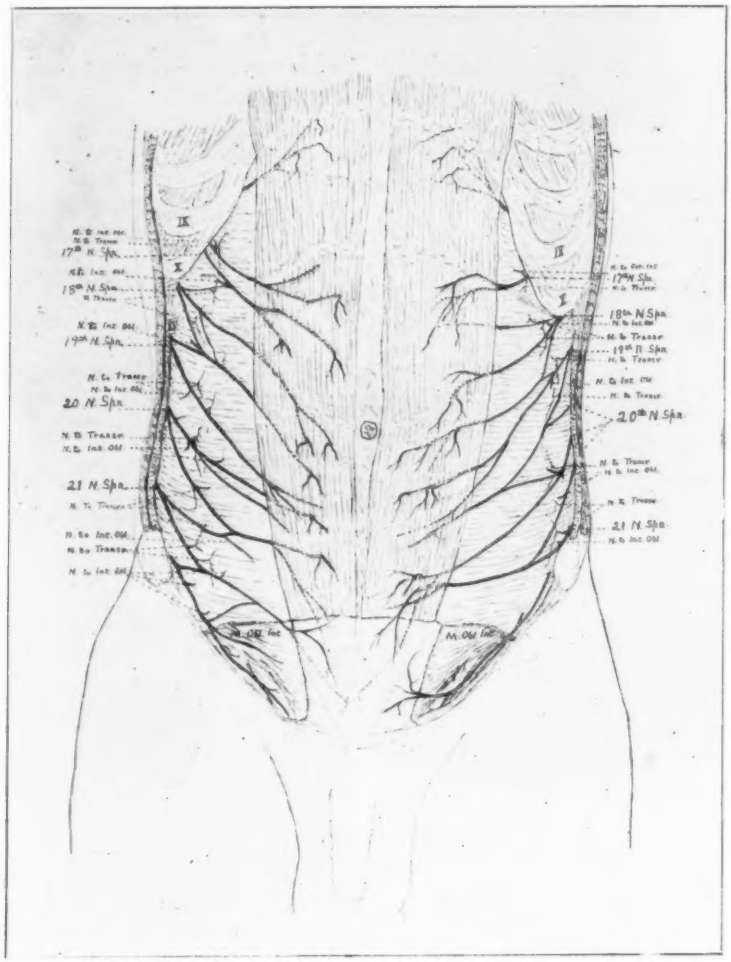

Fig. 2.

These outline schemes were well arranged and theoretically should have worked well. Yet they did not prove a success in the hands of the students. The suggestion induced by print seemed continually to lead the student into reading the scheme into his "part." The task of verifying the charts thus became a severe one. Another difficulty came from the fact that names can mean little so long as the "normal" is unknown. While the larger nerves are so constant in position that the names current in the text-books

could be used without confusion it was found that many of the smaller nerves could be definitely recorded only by attaching a special definition to the name. The *iliohypogastric* and the *genitocrural* nerves may be mentioned as examples. The value of these earlier charts lies rather in the illustrative diagrams of the plexuses placed on the backs of the charts than in the records made on the tabulation schemes.

In the fall of 1897 I undertook the immediate supervision of these records. I discarded to a considerable extent the use of the printed schemes. The students were encouraged to record the distribution of the nerves by making free-hand diagrammatic sketches to illustrate the conditions found in the parts dissected. Many of the drawings thus made were well executed. Yet few of the students are sufficiently skillful draughtsmen to make even these simple sketches without a great expenditure of time. I therefore devised a set of simple outline diagrams on which the nerve distribution can be recorded. These diagrams are arranged for the various parts of the body. Thus there is one for the abdomen, which can be used either for the nerves of the abdominal walls or for the lumbar plexus (see Figs. 1-3); another for the nerves of the front of the thigh; one for the sacral plexus; one for the perineum; one for the back of the thigh, etc., in all 26 charts.[2] Separate charts are used for the right and left sides of the body.

In these diagrams the bones and the surface outline of the body after the removal of the skin and the superficial fascia are indicated by fine lines printed in brown ink. The scale of the charts varies from one-half to full life size, according to the region to be charted. In this way the general average proportions of the various parts of the body are furnished the student. Marked variations from these proportions can readily be indicated by changing the faint outlines of the skeletal scheme. After removing the skin from a given part of the body the student draws on the appropriate diagram the course of the superficial nerves as he finds them running in the fascia. When the muscles have been dissected out the nerve supply of the various muscles is charted. Muscles and other structures are drawn in to show the general relations of

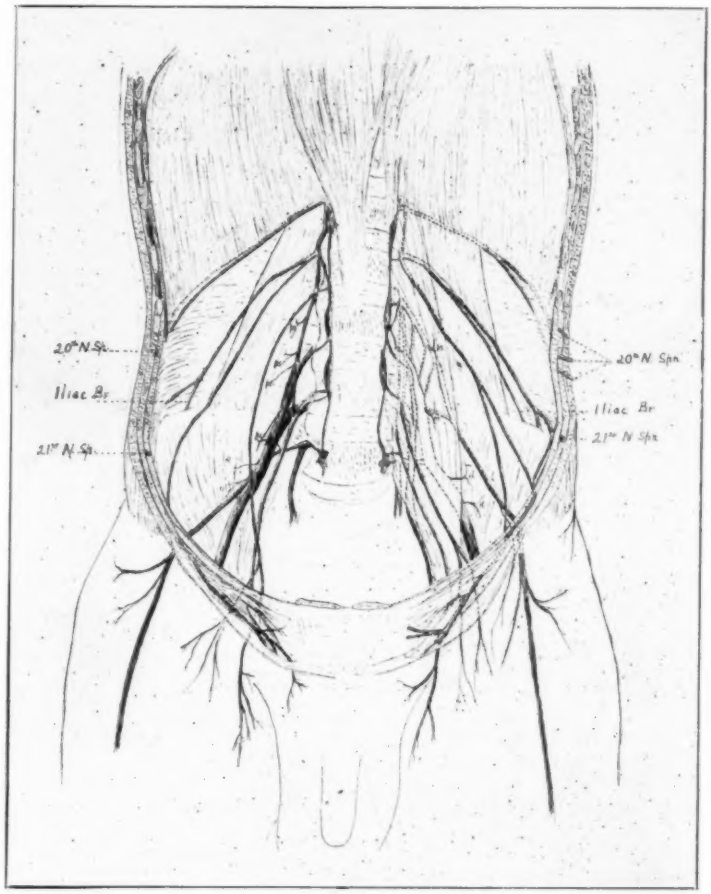

FIG. 3.

[2] These charts have been published in pamphlet form: "Outline Record Charts." The Johns Hopkins Press, Baltimore, 1900.

the nerves. The best records have been obtained when the student has attempted to record only a few simple conditions on a single chart. Thus in charting the nerves of the front of the thigh separate charts are used to record the distribu-

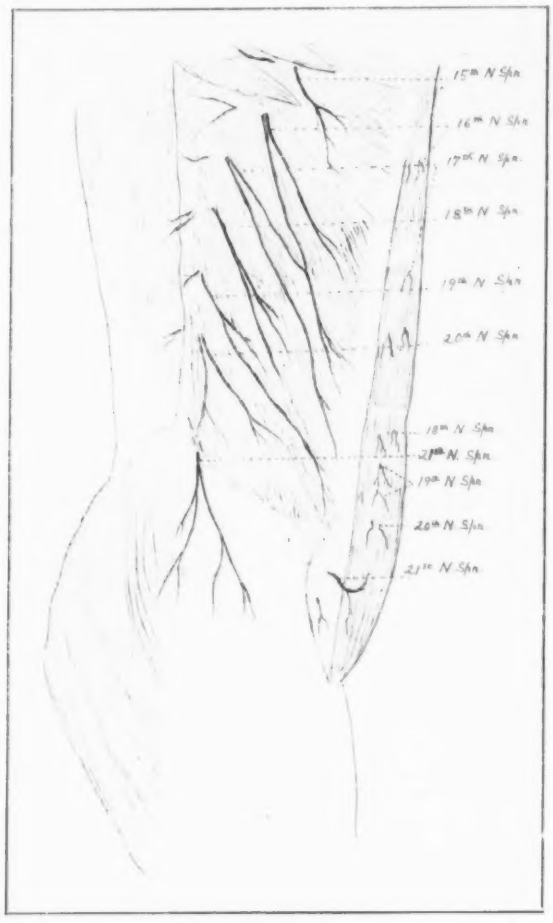

Fig. 4.

tion to the *sartorius* muscle, to the *rectus* muscle, to the *deep extensor* muscles, to the *adductor longus* muscle and the *gracilis*, to the *adductor brevis* muscle, and to the *adductor magnus* and *external obturator* muscles.

To illustrate the method of using these charts a few examples may be given. Fig. 1 represents the outline diagram used for the abdomen and the lumbar region. Fig. 2 shows the distribution of the main ventral trunks of the abdominal nerves as dissected out and recorded by two students. Fig. 3 represents the lumbar plexuses and the distribution of the "border nerves" found in the same subject. The lateral branches of the abdominal nerves are shown in another chart (Fig. 4).

Of course one cannot hope to get from students the complete and accurate records which one could get by personal dissection. It is only rarely that perfectly satisfactory records are obtained of the peripheral distribution of all the nerves. On the other hand, it would be a physical impossibility by personal dissection to get the same number of records in the same space of time. Mistakes are more likely to be those of omission than of a positive nature. The student may destroy some fine nerve twig before it has been seen by an instructor, and thus it may escape record. The conditions that the average student finds and records are, however, of great value. Thus only may we hope to get that large number of records from which a curve of frequency may be determined.

In addition to the outline diagrams I have devised a simple printed scheme for keeping record of the race, sex, age, size, skeletal peculiarities and marked variations from the normal in the various organs of the body. This latter set of records is made out by the instructor who verifies the charts.

The verification of the charts is one of the most important features of the undertaking. Without careful verification by one man who gives his time in the dissecting room mainly, if not wholly, to this task the charts can be of little value.

Active co-operation on the part of all the instructors and of the students in the dissecting room is also essential.

The conditions which at present prevail in our medical department render it also perhaps more than usually easy to get the co-operation of the students in carrying out work of this kind. The standards of admission to this school bring us a much more highly trained class of students than those usually found entering the average American medical school. On the other hand, the routine of a graded course, while inferior as a method of education to that freedom of choice which marks the German university, renders it much easier to win the co-operation of the students in this work. The number of students dissecting each year since the beginning of the undertaking has averaged about one hundred.

ON THE DEVELOPMENT OF THE HUMAN DIAPHRAGM.

By Franklin P. Mall,

Professor of Anatomy, Johns Hopkins University.

In a paper on the development of the human coelom, published several years ago, I was not able to give a detailed description of the separation of the body cavities from one another, because the specimens at my disposal did not include all the necessary stages. For that study I used 19 human embryos between 2 and 24 mm. long, in which various stages of the development of the body-cavities were shown, but a number of the important stages were missing.

[1] Mall, Jour. of Morph., vol. 12, 1897.

During the past three years the collection of human embryos in the anatomical laboratory has grown very rapidly and all the missing stages for the study of the formation of the body-cavities have been supplied. The following table gives a list of these embryos. It will be seen from it that

TABLE OF EMBRYOS.

No.	Greatest length in mm.	Time between the beginning of the last period and the abortion.	Direction of the section.	From whom obtained.
XII.	2.1	41 days	Transverse	Dr. Ellis, Elkton, Md.
CLXIV ...	3.5	...	"	Dr. MacCallum, Baltimore.
CXLVIII .	4.3	38 days	"	Dr. Hoen, Baltimore.
LXXVI...	4.5	...	"	Dr. Mitchell, Chicago.
LXXX ...	5	...	"	Dr. Branham, Baltimore.
CXXXVI .	5	56 days	Sagittal	Dr. Campbell, Halifax, N. S.
CXVI . ..	6.5	55 days	"	Dr. Ryan, Springfield, Ill.
II.....	7	52 days	Transverse	Dr. C. O. Miller, Baltimore.
CXIII	8	...	Sagittal	Dr. Gray, Washington.
CLXIII ..	9	5 weeks	Transverse	Dr. Lamb, Washington.
CXIV	10	...	Sagittal	Dr. Gray, Washington.
CIX.....	11	...	Transverse	Dr. Cushing, Baltimore.
CXLIV ...	14	...	Sagittal	Dr. Watson, Baltimore.
XLIII	16	...	"	Dr. Booker, Baltimore.
LXXIV...	19	...	Transverse	Dr. Irving Miller, Baltimore.

the series from 2 mm. upward is very complete with the exception of stages between 11 and 14 mm. long. Fortunately, the missing stages are not important. All the embryos given in this table are practically perfect, the imperfect ones having been excluded. The present study is based upon 15 embryos, only 3 of which are included in the 19 specimens considered in the earlier communication.

It has often been stated that the development of the diaphragm, especially in the human embryo, is one of the most difficult problems of embryology, party because of the difficulty in obtaining the necessary specimens and partly because there are no fixed points from which to calculate. In its development the whole diaphragm wanders from the head to the abdomen, passing by as well as modifying the structures and organs along the way. So, while von Baer recognized that the diaphragm wandered in its development, picking up its nerve in so doing, a fairly clear picture of the whole process was not given until His studied carefully the development of the neck, heart, lungs and intestine. In his studies His recognized the *Anlage* of the diaphragm in a mass of tissue located with the heart amongst structures belonging to the head and containing within it the veins to the heart as well as the *Anlage* of the liver. This mass of tissue His termed the septum transversum. His's studies were made upon the human embryo, mainly by the method of reconstruction, and shortly after they were published Uskow made a very careful study of the further growth of the septum transversum. Uskow recognized the great importance of two additional structures in the formation of the pericardium and adult diaphragm from the septum transversum; these he termed the *pleuro-pericardial membrane*, containing the phrenic nerve, and the *pillars* which form the dorsal ends of the diaphragm. The pillars of Uskow have been termed the *pleuro-peritoneal membranes* by Brachet, and as the latter term is more appropriate than the former I shall employ it in the present paper.

My own studies show that the pleuro-pericardial and pleuro-peritoneal membranes arise from a common structure, which extends from the lobe of the liver along the dorsal wall of the ductus Cuvieri to the dorsal attachment of the mesocardium. Later this structure grows towards the head to complete the pleuro-pericardial membrane and then towards the tail to complete the pleuro-peritoneal membrane. This structure, which I shall term the *pulmonary ridge*, is located in the sagittal plane of the body-cavity with cephalic and caudal horns on its dorsal side. The ductus Cuvieri lies between these horns (Fig. 29).

The purpose of this paper is to follow carefully the fate of the septum transversum and the origin and fate of the pulmonary ridge in the human embryo. In so doing it is of course necessary to consider the division of the body-cavity into the pericardial, pleural and peritoneal cavities. According to His, the body-cavity in early embryos is divided into the *Parietalhöhle* and *Rumpfhöhlen*. The communication between these spaces he has also termed the recessus parietalis. The parietal cavity from its earliest appearance contains the heart and is destined to form the pericardial cavity. I shall term it the pericardial cœlom. A portion of the recessus parietalis forms the pleural cavity; it surrounds the lung bud throughout its development and I shall term it the pleural cœlom. The remainder of the recessus parietalis to the origin of the liver has developed in it the liver and stomach; this is added to the general peritoneal cavity and I shall term it the peritoneal cœlom. In the early embryos the whole cœlom lies far out of place; in Embryo XII nearly the entire cœlom lies in the region of the head and neck and in the further development of these parts the cœlom with the surrounding organs wanders away from the head to its permanent location. As long as the serous cavities arising from the cœlom are in the process of wandering and are not fully separated from one another I shall term them pleural, pericardial and peritoneal cœlom; when they are fully established I shall call them cavities.

In Embryo XII, Fig. 1, the cœlom of the embryo forms a free space encircling the heart and extending on either side of the body over the omphalo-mesenteric veins to the root of the umbilical vesicle. This canal of communication has developed within it the lung, stomach and liver, and throughout its earlier development it measures in length about one-fourth of that of the body (Embryos XII, CXLVIII, LXXVI,

LXXX, II and CLXIII). The appearance of the lung and liver marks the subdivision of the cœlom into the pleural and peritoneal cœlom. With the development of the liver, lung and stomach the cœlom containing them gradually dilates until the embryo is about 9 mm. long, when the canal evaginates, so to speak, and turns the liver and stomach out into the general peritoneal cavity. The Wolffian body, which occupied the dorsal wall of this canal, gradually degenerates and the lung takes its place. From these statements it is readily inferred that the canal extending from the pericardial cœlom, His's recessus parietalis, gives rise to the pleural cœlom on its dorsal side and to the peritoneal cœlom on its ventral side. The line of division is formed by the pleuro-peritoneal membrane extending from the ductus Cuvieri to the adrenal.

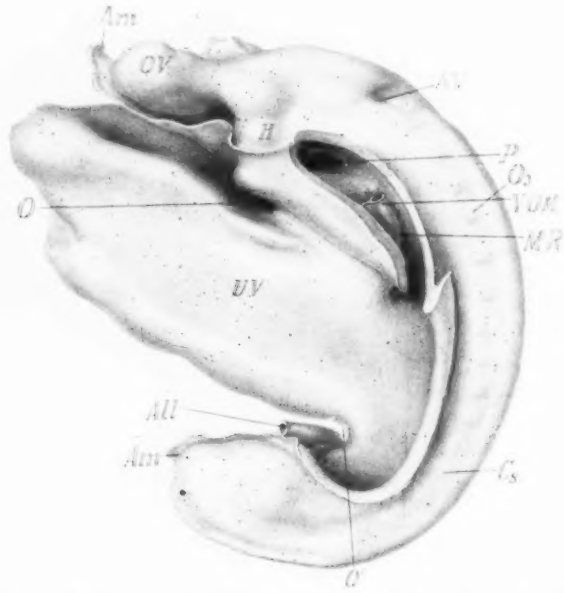

FIG. 1.—Profile reconstruction of the embryo 2.1 mm. long. No. XII × 37 times; *am*, amnion; *or*, optic vesicle; *ac*, auditory vesicle; *uv*, umbilical vesicle; *h*, heart; *vom*, omphalo-mesenteric vein; *mr*, septum transversum; o_3, third occipital myotome; C_8, eighth cervical myotome.

The earliest embryo in my collection in which the septum transversum is well formed is No. XII, 2.1 mm. long, and about two weeks old.[2] The specimen is very valuable for the study of the beginning of so many structures that it also becomes a good starting point for the study of the development of the diaphragm.

Figs. 1 and 2 give the external form and outline of the neural tube and alimentary canal drawn from a reconstruction. It is seen that the cœlom sends two canals into the head on either side of the neck which communicate with each other in the immediate neighborhood of the mouth. This U-shaped canal is separated from the exocœlom on its ventral side by a bridge of mesodermal tissue connecting the umbilical vesicle with the embryo at the juncture of the head with the amnion. It follows that this bridge of mesodermal tissue, the septum transversum, is also U-shaped, as is shown in Figs. 1 and 2, *ST* and *MR*. It forms a portion of the ventral wall of the pericardial cœlom and supports the omphalo-mesenteric and umbilical veins. Sections of it are shown in Figs. 3, 4 and 5, which are from three sections through the head end of this embryo in the neighborhood of the first cervical myotome. The *Anlage* of the liver is shown in Fig. 4, which is located in this stage in a region belonging to the head.

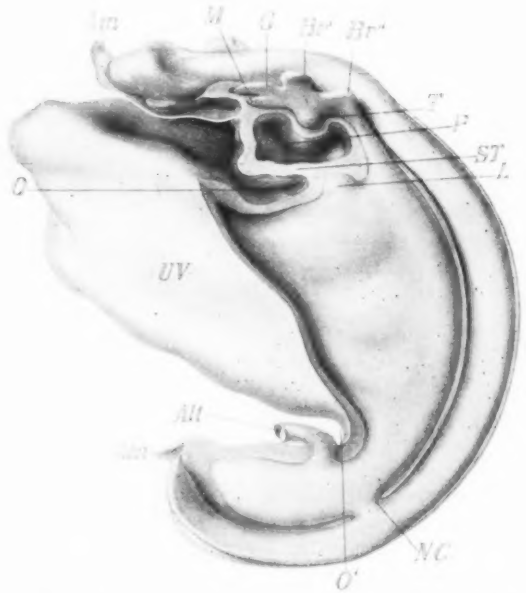

FIG. 2.—Partial dissection of the reconstruction of the embryo 2.1 mm. long. No. XII × 37 times; *am*, amnion; *m*, mouth; *Br'*, *Br''*, first and second branchial pockets; *t*, thyroid; *p*, pericardial cœlom; *st*, septum transversum; *l*, liver; *uv*, umbilical vesicle; *nc*, neurenteric canal.

Figs. 6 to 9 are from an embryo (CLXIV) slightly more advanced in development than No. XII. The embryo is from an ovum measuring 17 x 17 x 10 mm., found in the uterus at an autopsy. When the uterus was cut open the knife entered the ovum and possibly distorted the embryo, for when it came into my hands it was found that the embryo was floating in the cavity of the ovum but it was still adherent to its walls. This mechanical injury undoubtedly caused the body of the embryo to straighten and at the attachment of the umbilical vesicle the body of the embryo is bent towards the ventral side, as is the case in a number of the His embryos (for instance, BB). The ventral wall over the heart was also slightly torn. The entire uterus and ovum had been

[2] Different pictures of this embryo will be found in the Journal of Morph., vol. 12; His's Archiv, 1897; Johns Hopkins Hospital Bulletin, 1898; and the Welch Festschrift, Johns Hopkins Hospital Reports, vol. 9.

preserved on ice for 24 hours, and when it was given to me by Dr. MacCallum the entire specimen was placed in strong formalin. The sections of the embryo show that the tissues are slightly macerated but in general they are well preserved. The spinal cord is closed throughout its extent but the neuropore is still open. The thyroid gland, optic and otic

FIG. 3.—Section through the head of the embryo 2.1 mm. long. No. XII × 50 times; *coe*, coelom; *ph*, pharynx; *l*, liver; *st*, septum transversum; *ue*, umbilical vesicle.

vesicles, heart and veins, are but slightly more developed than in No. XII. If this embryo were curled up as No. XII it would measure from 2.5 to 3 mm., while if the two had been hardened in the same way (No. XII was hardened in alcohol) they would probably measure alike.

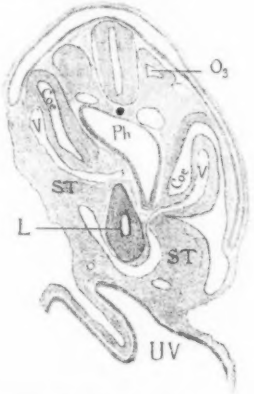

FIG. 4.—Section through the third occipital myotome of the embryo 2.1 mm. long. .04 mm. nearer the tail than Fig. 3 × 50 times; O_3, third occipital myotome; *coe*, coelom; *v*, vein; *st*, septum transversum; *l*, liver; *ph*, pharynx; *ue*, umbilical vesicle.

The figures given show the general relation as seen in Embryo XII with each of the structures but slightly advanced. The septum transversum is much the same as it is in XII, while the pericardial cœlom is pushed more to the ventral side of it and the diverticulum to form the liver is more marked. The umbilical vein has extended somewhat (Fig. 9) and the jugular vein has made its appearance (Fig. 7).

The tissue of the septum transversum in the two embryos is formed of irregular round cells, between which there are numerous vessels, of irregular diameter, which communicate freely with the veins to the heart.

The next stage of the development of the septum trans-

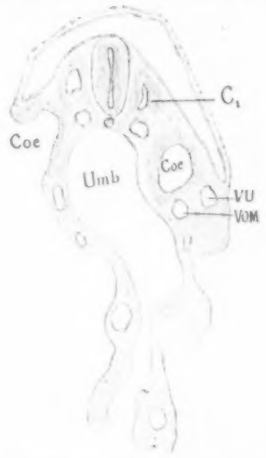

FIG. 5.—Section through the first cervical myotome of the embryo 2.1 mm. long, .23 mm. nearer the tail than Fig. 4 × 50 times; C_1 first cervical myotome; *coe* coelom; *vu*, umbilical vein; *vom*, omphalo-mesenteric vein; *umb*, umbilical vesicle.

versum is found in an embryo 4.3 mm. long (CXLVII), obtained from Dr. Hoen.[3] The specimen is perfect and normal, as it was obtained through mechanical means. The entire

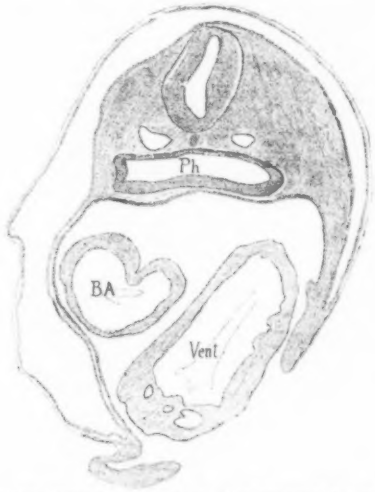

FIG. 6.—Section through the head of the embryo 3.5 mm. long. No. CLXIV × 50 times; *ph*, pharynx; *ba*, bulbus aortae; *vent*, ventricle.

ovum was hardened in 80 per cent alcohol shortly after it was expelled from the uterus. This of course fixed the embryo in its natural shape, as was the case with No. XII. Both embryos are curved, but in the embryo 4.3 mm. long the branchial region occupies relatively more space than it

[3] A photograph of this embryo is given in the Welch Festschrift.

does in the embryo 2.1 mm. long. In proportion to the length of the embryos this distance has increased 3 times. The pericardial cœlom has receded from the head in proportion to the increase of the growth of the branchial arches. In the embryo 2.1 mm. long the head end of the pericardial cœlom is opposite the otic vesicle, while in the embryo 4.3

FIG. 7.—Section through the embryo 3.5 mm. long, .14 mm. nearer the tail than Fig. 6 × 50 t mes; *ph*, pharynx; *ao*, auricle; *vent*, ventricle; *st*, septum transversum; *cj*, jugular vein; *vu*, umbilical vein.

mm. it is opposite the first occipital myotome. The point of communication between the peritoneal cœlom (encircling the liver) with the exocœlom has also receded. In the embryo 2.1 mm. long it is opposite the second cervical myotome; in embryo 4.3 mm. long opposite the second thoracic myotome

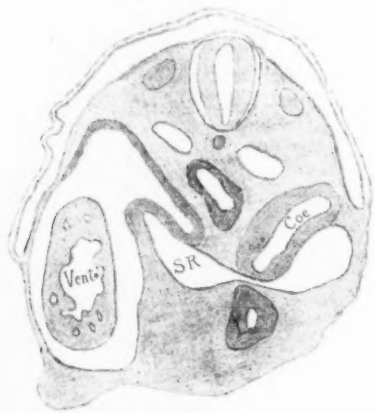

FIG. 8.—Section through the embryo 3.5 mm. long, .2 mm. nearer the tail than Fig. 7 × 50 times; *l*, liver; *vent*, ventricle; *sr*, sinus reuniens; *coe*, coelom.

(compare Figs. 1 and 10). His's embryo *Lr* (4.2 mm. long) is intermediate between the two embryos just compared. In *Lr* (see His's Atlas, Pls. IX and XI) the pericardial, pleural and peritoneal cœlom encircling the liver extends from the first occipital myotome to the sixth cervical, and the omphalo-mesenteric veins protrude into these canals of the cœlom. The liver has extended into the septum transversum but does not yet encircle the omphalo-mesenteric veins as it does in my embryo 4.3 mm. long. This detailed description is given to show the fate of the cœlom[1] of the head and neck. It gives rise to the pericardial and pleural cavities, and that portion of the peritoneal cavity encircling the liver of the adult.

Sections of the embryo 4.3 mm. long (No. CXLVIII, Figs. 11 and 12) show the liver sprouts growing in all direc-

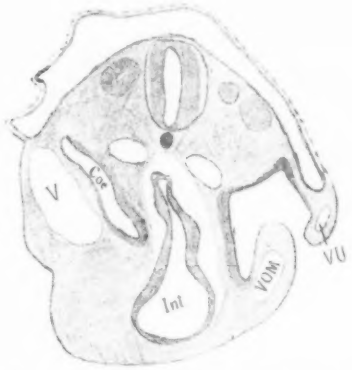

FIG. 9.—Section through the embryo 3.5 mm. long, .18 mm. nearer the tail than Fig. 8 × 50 times; *coe*, coelom; *int*, intestine; *vom*, omphalo-mesenteric vein; *vu*, umbilical vein.

tions through the septum transversum, encircling and ramifying through the omphalo-mesenteric veins, making a condition slightly in advance of that in His's embryo *Lr*. The sections of this embryo show clearly that the heart, lungs, liver and lower peritoneal cavity arise in tissues surrounded by that portion of the cœlom extending into the head in Embryo XII.

FIG. 10.—Outline of the embryo 4.3 mm. long. No. CXLVIII × 15 times. C_1, first cervical myotome; C_8, eighth cervical myotome. The line indicates the direction of the sections.

Fig. 1. Fig. 11 is taken from a section through a plane cutting the root of the arm and the otic vesicle, and can readily be placed in the outline, Fig. 10. It is seen that the lungs arise where the pericardial cœlom goes over into the pleural, *i. e.* high up in the region of the head. Immediately on the dorsal side of them is the beginning of the lesser peritoneal

[1] Kopfhöhle; Halshöhle; Parietalhöhle and recessus parietalis.

cavity, and the intestinal tube struck in this section is the stomach. All these structures lie on the cephalic side of the first cervical myotome. Projecting into the peritoneal cœlom, encircling and penetrating the omphalo-mesenteric veins are the projections of the liver, Figs. 11 and 12, *L*. The two lobes reach from the tip of the lungs and the foramen of Winslow to the point where the entodermal cells of the liver arise from

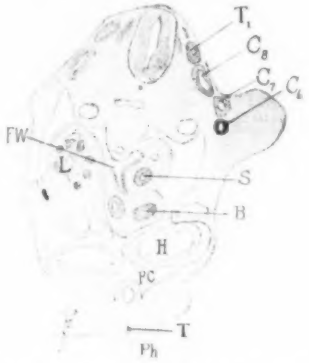

Fig. 11.—Section through the embryo 4.3 mm. long × 25 times; T_1, first thoracic myotome; C_6, C_7, and C_8, cervical myotomes; *s*, stomach; *fb*, bronchus; *h*, heart; *t*, thyroid; *pc*, pericardial cavity; *l*, liver; *fw*, foramen of Winslow.

the alimentary canal, or in this case the duodenum. The lobes of the liver lie entirely within the canals of the cœlom on either side of the head. The caudal ends of these cœlom canals have migrated from opposite the second cervical myotome in Embryo XII, Fig. 1, to opposite the second thoracic

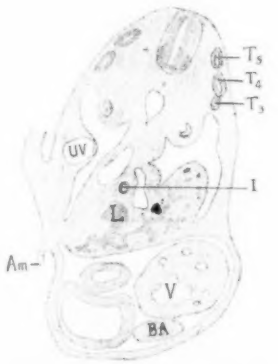

Fig. 12.—Section through the embryo 4.3 mm. long, .4 mm. deeper than Fig. 11 × 25 times; *t*, thoracic myotomes; *i*, intestine; *l*, liver; *v*, ventricle; *ba*, bulb of the aorta; *am*, amnion; *uv*, umbilical vein.

myotome in Embryo CXLVIII, Fig. 10. It has moved towards the tail eight segments, while the cephalic end of the canal, the pericardial cœlom, has been kinked over to correspond with the bending of the head, has dilated to correspond with the growth of the heart, and has receded from the otic vesicle to the extent of the growth of the branchial arches. We have in this embryo the necessary stage to locate the organs which arise in the neighborhood of the septum transversum, as well as to give the fate of the cœlom in their immediate neighborhood.

A stage somewhat in advance of CXLVIII is LXXVI. The embryo is slightly larger, measuring 4.5 mm. in greatest length. It was obtained from the uterus 7 hours after death. The entire ovum was placed immediately in absolute alcohol.

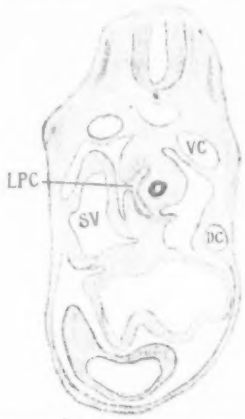

Fig. 13.—Section through the embryo 4.5 mm. long. No. LXXVI × 25 times; *cv*, cardinal vein; *lpc*, lesser peritoneal cavity; *dc*, ductus Cuvieri; *sv*, sinus venosus.

It was impossible to obtain a picture of the embryo before it was cut, but the specimen proved to be an excellent one. The direction of the sections is more nearly transverse than

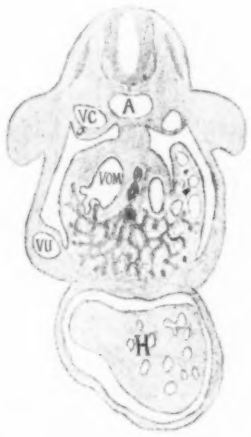

Fig. 14.—Section through the embryo 4.5 mm. long, .6 mm. deeper than Fig. 13 × 25 times; *cv*, cardinal vein; *a*, aorta; *com*, omphalo-mesenteric vein; *vu*, umbilical vein; *h*, heart.

in CXLVIII. In CXLVIII the neuropore is closed with a thickening of the epidermis just over the point of closure; the umbilical vein enters the liver and its direct connection with the ductus Cuvieri through the body wall is cut off. In LXXVI the neuropore is completely closed and the embryo is somewhat larger than before (compare Figs. 13 and 14 with 11 and 12); the umbilical vein, however, communicates with the ductus Cuvieri through the body-wall on the left

side. This is an instance of retarded development of a part, as the left umbilical vein should have vanished by this time.

Fig. 13 gives a section through the foramen of Winslow immediately on the caudal side of the lung buds, as shown in a lateral view of the model of the embryo, Fig. 15. The

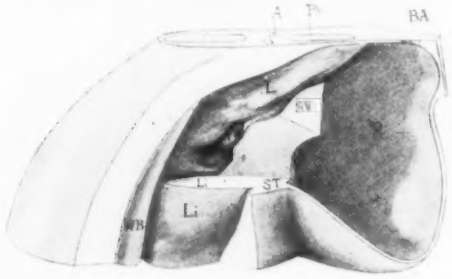

Fig. 15.

septum transversum and liver have increased in quantity, as a comparison of the different figures will show. In this

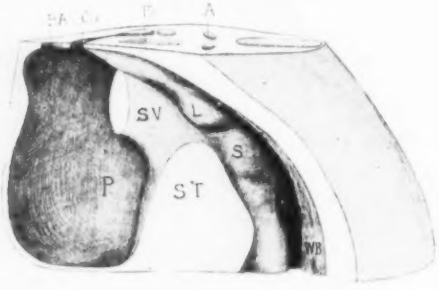

Fig. 16.

Figs. 15 and 16.—Right and left views of a reconstruction of the embryo 4.5 mm. long × 25 times; *a*, aorta; *ph*, pharynx; *ba*, bulbus aortæ; *cœ*, cœlom; *p*, pericardial cœlom; *l*, lung; *li*, liver; *Wb*, Wolffian body; *s*, stomach; *fw*, foramen of Winslow; *se*, sinus venosus; *st*, septum transversum.

stage we have the extreme bending of the head, which throws the heart to its most ventral point with the septum transversum about parallel with long axis of the embryo. The

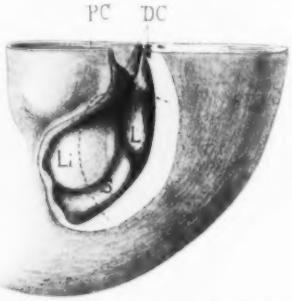

Fig. 17.—Lateral view of the reconstruction of an embryo 5 mm. long. No. LXXX × 17 times; *l*, lung; *li*, liver; *s*, stomach: dc, ductus Cuvieri; *pc*, pericardial cœlom which communicates fully with pleuro-peritoneal cœlom.

position of the heart, lungs, liver and their relation to the cœlom is much the same as in the younger embryo with the exception of the lesser peritoneal cavity, which is now more to the caudal side of the lungs.

While in the embryo 4.3 mm. long the myotomes were well formed and hollow, in the embryo 4.5 they are solid and contain embryonic muscle fibres. The dorsal ganglia are also

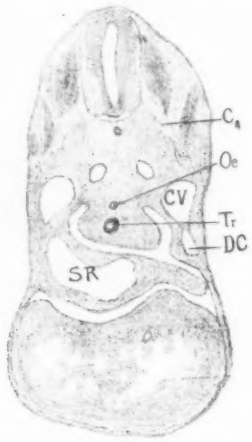

Fig. 18.—Section through the neck and heart of embryo LXXX × 25 times; C_4, fourth cervical nerve; *cv*, cardinal vein; *dc*, ductus Cuvieri; *oe*, oesophagus; *tr*, trachea; *se*, sinus reuniens.

more developed. In the embryos 5 mm. long (LXXX and CXXXVI) the myotomes are still further differentiated with nerve trunks, composed of both dorsal and ventral roots, which are growing into the body-walls of the embryo. Figs. 17-20 give the general form of this embryo, in reconstruction

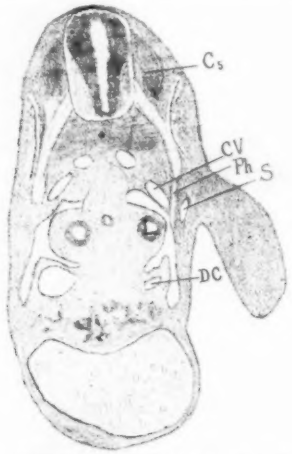

Fig. 19.—Section through embryo LXXX .22 mm. deeper than Fig. 18 × 25 times; C_5, fifth cervical nerve; *cv*, cardinal vein; *s*, subclavian vein; *dc*, ductus Cuvieri; *l*, lung; *ph*, phrenic nerve.

as well as in section. The septum transversum is not as perpendicular as in either younger or older stages (LXXVI and II), but in general this embryo is intermediate between them. A separation between the pericardial and pleural cœlom now begins to make its appearance by means of a constriction in its walls, the ductus Cuvieri encircling the cœlom at this point. The lung buds hang free into the pleural cœlom,

and the liver and stomach into the peritoneal cœlom. The ductus Cuvieri lies in a ridge of tissue encircling the canal of communication between the pericardial and pleural cœlom. In this embryo the ridge has no mesentery, as described by His (Fig. 18), but in sagittal sections of the same stage (CXXXVI) the mesentery is present. As yet there is no

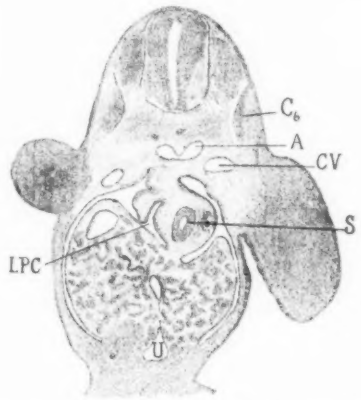

Fig. 20.—Section through embryo LXXX, .26 mm. deeper than Fig. 19 × 25 times; C_6, sixth cervical myotome; *a*, aorta; *cv*, cardinal vein; *s*, stomach; *u*, umbilical vein; *lpc*, lower peritoneal cavity.

indication of a line of separation between the pleural and peritoneal cœlom in LXXX, but in CXXXVI there is an elevation on the dorsal wall of the pleural cœlom, Fig. 21, which encircles the lung and joins the dorsal end of the septum transversum. This is one of the pillars of Uskow

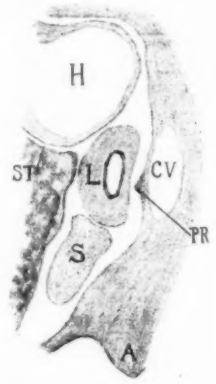

Fig. 21.—Sagittal section through an embryo, 5 mm. long. No. CXXXVI × 25 times; *h*, heart; *cv*, cardinal vein; *st*, septum transversum; *l*, lung; *s*, stomach; *a*, arm; *pr*, pulmonary ridge.

or the beginning of a ridge which I shall term the *pulmonary ridge*.

Fig. 20, compared with Fig. 13, shows that the foramen of Winslow has moved more rapidly towards the tail than the heart. A section through it strikes the heart squarely in one case, while in the other it does not touch the heart but strikes the liver only. This is in part due to the direction of the section in the two specimens, and in part to the shifting of the foramen of Winslow with the recession of the stomach. The cervical nerves are separated in No. LXXX with the exception of an anastomosis between the fourth and the fifth. From this point the phrenic nerve arises, Fig. 19, and passes to the lateral side of the parietal cœlom and lung. In a later stage it reaches the septum transversum through the pleuro-pericardial membrane of Uskow.

I have now followed the transformation of the relatively simple cœlom of the head and neck from the time it is well formed in an embryo of the end of the second week to the end of the third week. During this time the pericardial cœlom has moved away from the head and the pericardial cavity is well outlined, but the membranes which divide the cœlom into pericardial, pleural and peritoneal spaces have not yet

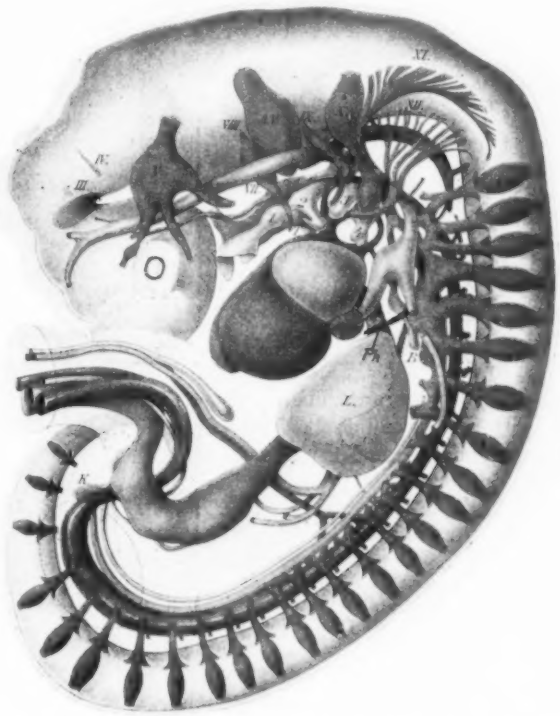

Fig. 22.—Reconstruction of embryo No. II × 20 times; *B*, bronchus; *L*, liver; *Ph*, phrenic; *1*, *2*, *3*, *4* branchial pouches.

appeared. During the fourth week both of these membranes appear, but they are not well defined until the fifth week.

Fig. 22 is from a profile reconstruction of Embryo II, showing the relation of the organs to one another. A cast of the colon of this embryo is given in Fig. 23. The extreme ventral kinking of the heart is shown in this stage and from now on it begins to sink more and more into the body as the liver recedes. The communication between the pericardial cœlom and the pleural cœlom is reduced to a narrow slit between the cephalic end of the lung bud and the ductus Cuvieri. It appears as if a simple adhesion of the walls of the slit would complete the closure of the pericardial space. Fig. 24 is a section through this space, striking the seventh cervical myo-

tome and the tip of the phrenic nerve. It shows that the attachment of the ductus Cuvieri is no longer broad, as in embryo LXXX, but is narrow, forming a mesentery as described by His. On the dorsal side of the ductus there is a ridge which begins as the ductus projects into the cœlom and gradually runs over into the lobe of the liver. This ridge is very pronounced and is also well shown in the sections of His's embryos, A and B, as given in his *Atlas*. The relation of this ridge to the phrenic nerve as well as its form in older embryos makes of it the *Anlage* of both the pleuro-pericardial and pleuro-peritoneal membranes. It lies in the sagittal plane of the cœlom and as it passes the region of the fourth and fifth cervical nerves receives into its substance the phrenic nerve which passes on the caudal side of the ductus Cuvieri. Soon the lung bud grows against this ridge, causes it to bulge, and with the rotation of the liver towards the head the ridge is divided into two parts: (1) the cephalic end which retains the phrenic nerve and ductus Cuvieri and forms the pleuro-pericardial membrane, and (2) the caudal end which remains attached to the tip of the dorsal end of the septum transversum and the liver on the one hand, the body-wall on the other, to form the pleuro-peritoneal membrane.

FIG. 23.—Cast of cœlom of embryo II × 20 times: *P*, pericardial cœlom; *L*, cœlom encircling to liver.

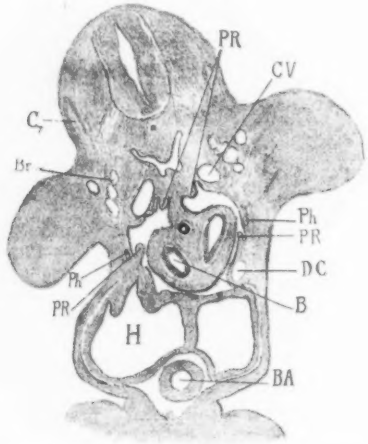

FIG. 24.—Section through the seventh cervical segment of the embryo 7 mm. long. No. II × 25 times; C_7, seventh cervical myotome; *cv*, cardinal vein; *dc*, ductus Cuvieri; *br*, brachial plexus; *pr*, pulmonary ridge; *ph*, phrenic nerve; *b*, bronchus; *h*, heart; *ba*, bulbus aortæ.

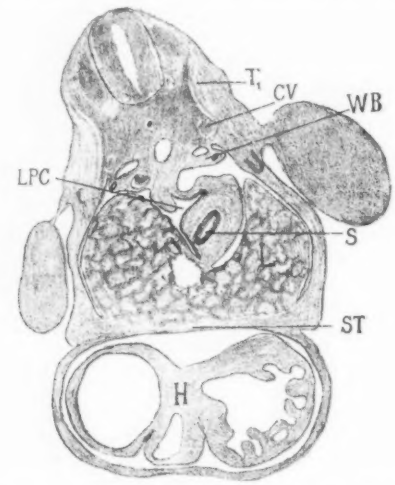

FIG. 25.—Section through the embryo 7 mm. long, .6 mm. deeper than Fig. 24 × 25 times; T_1, first thoracic myotome; *cv*, cardinal vein; *Wb*, Wolffian body; *s*, stomach; *lpc*, lesser peritoneal cavity; *l*, liver; *h*, heart; *st*, septum transversum.

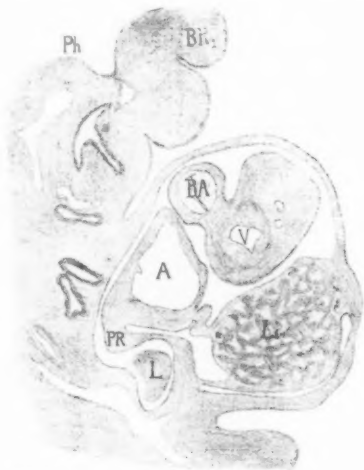

FIG. 26.—Sagittal section through the embryo 6.5 mm. long. No. CXVI × 25 times; *ph*, pharynx; *br'*, first branchial arch; *ba*, bulbus aortæ; *a*, auricle; *v*, ventricle; *l*, lung; *li*, liver; *pr*, pulmonary ridge.

Figs. 26-28 show this ridge in sagittal sections in Embryo CXVI, a specimen not quite as large as No. II, but somewhat

more advanced in development. In Fig. 26 its cephalic end appears as a broad membrane which in a section nearer the middle line extends to the liver on the ventral side and it begins to widen at its dorsal end hand in hand with the rotation of the liver. Up to this time the septum transversum is parallel with the vertebral column, with the heart

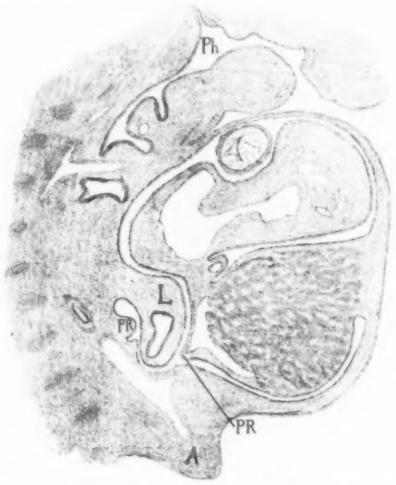

FIG. 27.—Section through the embryo 6.5 mm. long, .1 mm. deeper than Fig. 26 × 25 times, *ph*, pharynx; *a*, arm; *pr*, pulmonary ridge; *l*, lung.

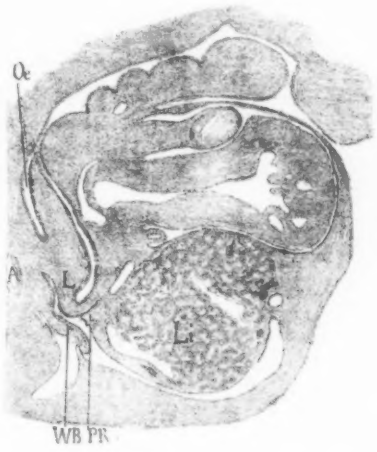

FIG. 28.—Section through the embryo 6.5 mm. long, .12 mm. deeper than Fig. 27 × 25 times; *oe*, oesophagus; *a*, aorta; *l*, lung; *li*, liver; *Wb*, Wolffian body; *pr*, pulmonary ridge.

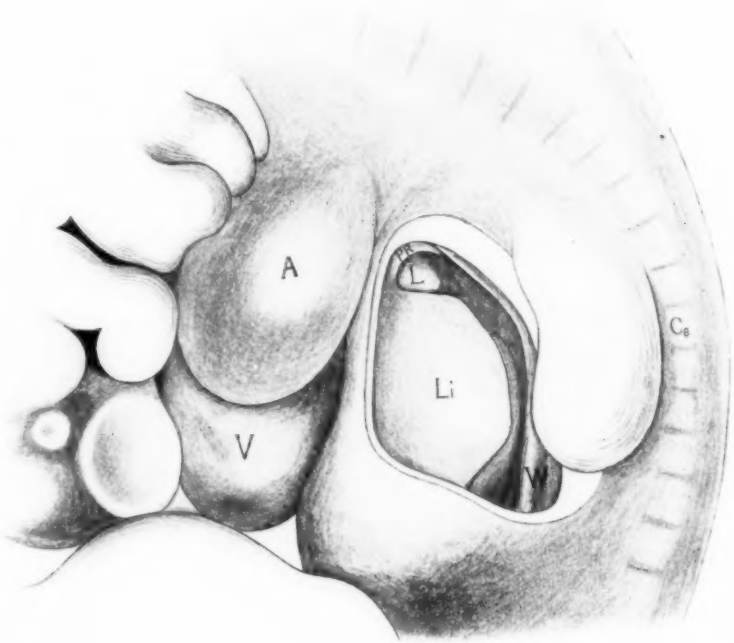

FIG. 29.—Lateral view of the pulmonary membrane and surrounding parts of the embryo 7 mm. long. No. II × 30 times; *a*, auricle; *v*, ventricle; *l*, lung; *li*, liver; *Wb*, Wolffian body; *pr*, pulmonary ridge; C_8, eighth cervical myotome.

accompanies the ductus Cuvieri to the body-wall on the dorsal side, Fig. 27, *pr*. Stil more towards the midline the ridge ends as a decided elevation immediately to the caudal side of the tip of the lung.

After the pulmonary ridge is well formed (as in Embryo II) on its ventral side and the liver on its dorsal side projecting into the peritoneal cœlom, as shown in No. II. This condition was brought about at the time of the bending of the head when the viscera were forced towards the tail and into this position. The cephalic end of the pericardial cœlom

is thus bent over the septum transversum but the main part of the head cœlom remained parallel with the spinal column on either side of the body. This process may be termed the rolling over of the heart.

In the next stage the heart rolls in a dorsal direction and the liver in a ventral direction. This process has already begun in embryo CLXIII and CXIII. In so doing the lung buds become buried deeper in the body of the embryo and the liver gradually changes its position from the dorsal side

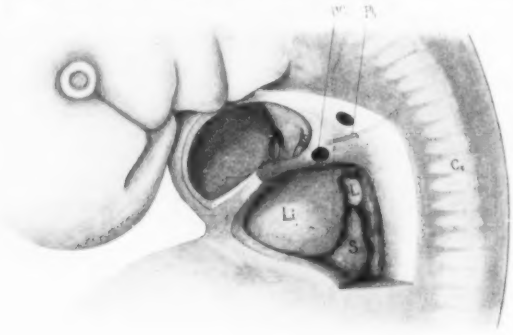

FIG. 30.—Lateral view of the pulmonary membrane and surrounding parts of the embryo 9 mm. long; No. CLXIII × 12½ times, C_6, eighth cervical myotome; *li*, liver; *l*, lung; *s*, stomach; *Wb*, Wolffian body; *ph*, phrenic nerve; *pc*, pleuro-pericardial membrane; *pp*, pleuro-peritoneal membrane.

of the septum transversum to its ventral side. The septum transversum undergoes almost a half-revolution. The cœlom containing the liver lobe evaginates and becomes incorporated with the general abdominal cavity.

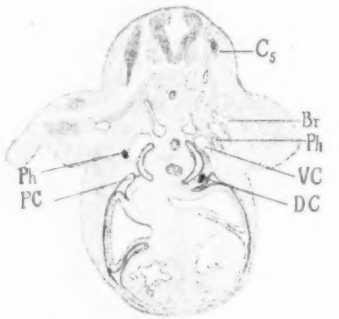

FIG. 31.—Section through the fifth cervical myotome of the embryo 9 mm. long, No. CLXIII × 12½ times; C_5, fifth myotome; *cv*, cardinal vein; *dc*, ductus cuvieri; *br*, brachial plexus; *ph*, phrenic nerve; *pc*, cephalic end of the pulmonary ridge forming the beginning of the pleuro-pericardial membrane.

With the rolling of the heart the cœlom connecting the pericardial with the pleural space is kinked at the points of juncture between these cavities. At this point the duct of Cuvier enters the heart. Soon from its dorsal border the pulmonary ridge arises which is semicircular in form and reaches from the liver to the dorsal walls of the cœlom as described under Embryo II. It is shown in section in Fig. 24, and in a lateral reconstruction in Fig. 29. The pulmonary ridge is really an extension of the septum transversum from the lobes of the liver to the tip of the Wolffian body. As the heart moves in the dorsal direction and the liver in the ventral direction it is the dorsal end of the septum transversum which moves most rapidly in the direction of the tail. In so doing the pulmonary ridge grows rapidly and divides at its dorsal end into two membranes, one containing the duct of Cuvier and phrenic nerve, and the other still encircling the lung bud. In this division we have the beginnings of the pleuro-pericardial membrane of Uskow, and the pleuro-peritoneal membrane of Brachet.

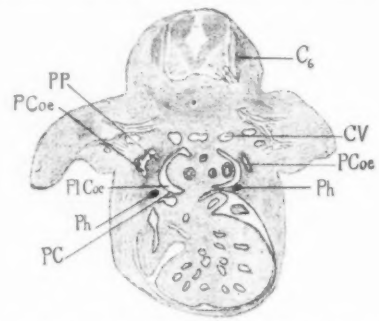

FIG. 32.—Section through the embryo 9 mm. long, .16 mm. deeper than Fig. 31 × 12½ times; C_6, sixth cervical myotome; *cv*, cardinal vein; *ph*, phrenic nerve; *pc*, pleuro-pericardial membrane; *pp*, pleuro-peritoneal membrane; *pl-coe*, pleural coelom; *p-coe*, peritoneal coelom.

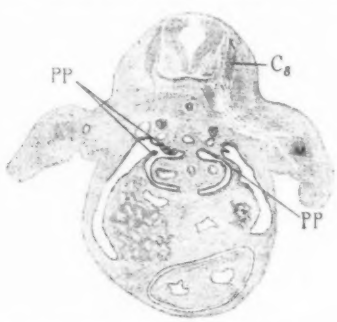

FIG. 33.—Section through the embryo 9 mm. long, .16 mm. deeper than Fig. 32 × 12½ times; C_8, eighth cervical nerve; *pp*, pleuro-peritoneal membrane.

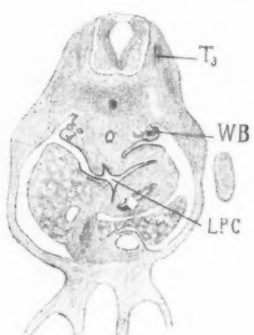

FIG. 34.—Section through the embryo 9 mm. long, .84 mm. deeper than Fig. 33 × 12½ times; T_3, third thoracic myotome; *lpc*, lower peritoneal cavity; *Wb*, Wolffian body.

The pulmonary ridge is well formed in Embryo II. It appears as a ridge of tissue passing towards the head from the lobe of the liver on the dorsal side of the ductus Cuvieri and then along the dorsal walls of the coelom to the meso-

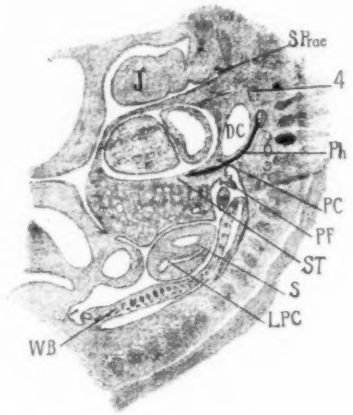

FIG. 35.—Sagittal section through the embryo 8 mm. long, No. CXIII × 10 times; *j*, lower jaw; *s-prae*, sinus praecervicalis; *4*, fourth cervical nerve, *ph*, phrenic nerve; *st*, septum transversum; *dc*, ductus Cuvieri; *pc*, pleuro-pericardial membrane; *pp*, pleuro-peritoneal membrane; *l*, lung; *s*, stomach; *lpc*, lower peritoneal cavity; *Wb*, Wolffian body.

cardium, where it ends in the pillars of Uskow. As the embryo grows larger the ductus Cuvieri separates more and more from the lateral body-wall, and in a measure shifts into the pulmonary ridge, which at its most convex point grows in the form of a ridge towards the heart. This secondary ridge, which is present in CLXIII, finally separates the pleural from the pericardiai cavities and completes the pleuro-pericardial membrane.

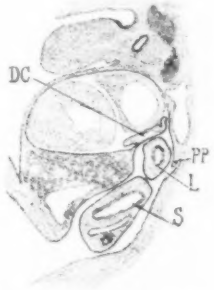

FIG. 36.—Section through the embryo 8 mm. long nearer the middle line than Fig. 35 × 10 times; *dc*, ductus Cuvieri; *l*, lung; *s*, stomach; *pp*, pleuro-peritoneal membrane.

The pulmonary ridges from their beginning to their separation into the pleuro-pericardial and pleuro-peritoneal membranes appear as two ears to the septum transversum, extending along the ducts of Cuvier in the sagittal plane of the body and at right angles to the plane of the septum transversum. Judging by the relation of the phrenic nerve to the pulmonary ridge the portion of it on the dorsal side of the ductus Cuvieri containing the phrenic nerve, the portion containing the ductus Cuvieri, and the secondary ridge of the ventral side of the ductus Cuvieri, form the pleuro-pericardial membrane. The portion of the pulmonary ridge on the caudal side of the phrenic nerve gives rise to the pleuro-peritoneal membrane. In so doing it gradually shifts over

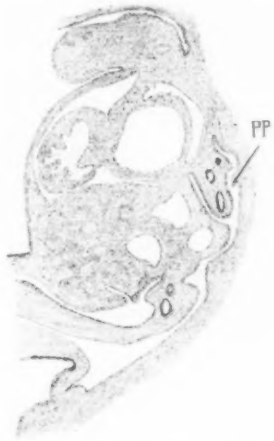

FIG. 37.—Sagittal section through the embryo 10 mm. long. No. CXIV × 10 times; *pp*, pleuro-peritoneal membrane.

the lung buds and finally completely separates the pleural from the peritoneal cavities.

The growth of the pleuro-pericardial membrane towards

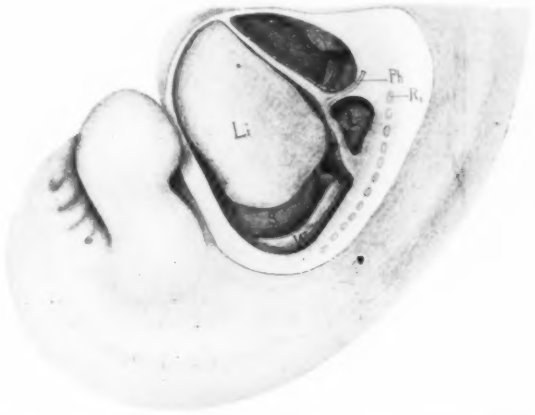

FIG. 38.—Lateral view of the embryo 11 mm. long, showing the pleuro-pericardial and pleuro-peritoneal membranes. No. CIX × 8½ times; *r*₁ first rib; *l*, lung; *li*, liver; *ph*, phrenic nerve in the pleuro-pericardial membrane; *s*, stomach; *Wb*, Wolffian body; *pp*, pleuro-peritoneal membrane which is not quite completed.

the head and the pleuro-peritoneal towards the tail widens the dorsal projection of the septum transversum and into this wide base the lung burrows throwing the pleuro-pericardial membrane with the phrenic nerve to its medial side.

The fate of the pulmonary ridge is shown in Fig. 30, which is from Embryo CLXIII. Sections of this embryo are shown in Figs. 31 to 34. They show again that the pulmonary ridge reaches from the ductus Cuvieri to the tip of the lung, and the phrenic nerve. It is readily seen from Figs. 30 and

32 how the phrenic nerve is pushed to its permanent position by the further rotation and recession of the septum transversum and liver, and the lateral growth of the lungs to encircle the heart.

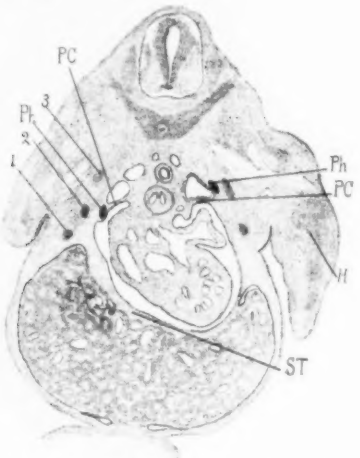

FIG. 39.—Section through the body of the embryo 11 mm. long. No. CIX × 10 times; *ph*, phrenic nerve; *pc*, pleuro-pericardial membrane; *st*, septum transversum; *h*, humerus; *1*, first rib; *2*, second rib; *3*, third rib.

Figs. 35 and 36 are from sagittal sections of Embryo CXIII, which is of the same stage as CLXIII. The phrenic nerve is shown throughout its whole course from the fifth cervical nerve to the pleuro-pericardial membrane. The nerve receives a second branch a few sections deeper from the sixth cervical which unites with the main trunk before it enters

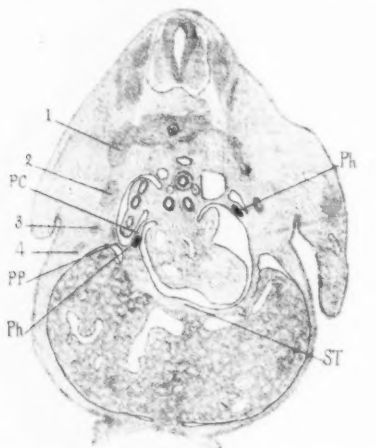

FIG. 40.—Section through the embryo 11 mm. long; .18 mm. deeper than Fig. 39 × 10 times; *ph*, phrenic nerve; *st*, septum transversum; *pc*, pleuro-pericardial membrane; *pp*, pleuro-peritoneal membrane; *1*, *2*, *3*, *4*, ribs.

the pleuro-pericardial membrane. Hanging from the pleuro-pericardial membrane is a section of the pleuro-peritoneal, which in Fig. 36 unites with the dorsal wall of the coelom at the head end of the Wolffian body.

About this time the portion of the pulmonary ridge destined to become the pleuro-pericardial membrane unites with the root of the lung bud and completely closes the pericardial cavity, Fig. 37. By this union the course of the ductus Cuvieri is from the body-wall to the heart through the pleuro-pericardial membrane, and the plane of the pleuro-pericardial

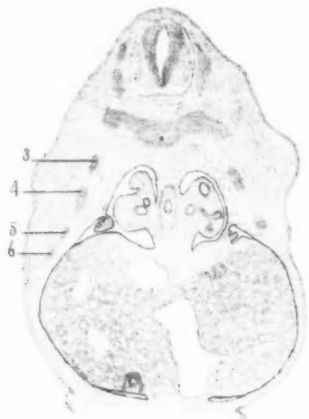

FIG. 41.—Section through the embryo 11 mm. long, .46 mm. deeper than Fig. 40 × 10 times. The pleuro-peritoneal membrane is incomplete on one side. *3*, *4*, *5*, *6*, ribs.

membrane is practically that of the septum transversum, the two together being transverse to the body of the embryo. The phrenic nerve at this time is in the plane of the septum transversum and reaches its dorsal tip through its projection, the pleuro-pericardial membrane.

Immediately after the completion of the pleuro-pericardial

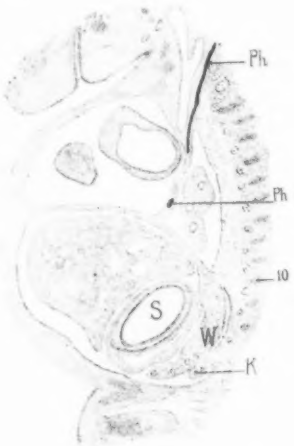

FIG. 42.—Sagittal section through the embryo 14 mm. long. No. CXLIV × 10 times, *ph*, phrenic nerve; *10*, tenth rib; *s*, stomach; *k*, kidney; *W*, Wolffian body.

membrane the rotation of the liver and septum transversum is accelerated, and by the time the embryo has grown to be 11 mm. long (CIX), the liver is practically in its adult position. The rapid rotation of the liver, especially at its dorsal end, has changed the relation of the planes between the

pleuro-pericardial membrane to the septum transversum from parallel to right angles. Now the septum transversum is in the plane of the pleuro-peritoneal membrane (Fig. 38). With the recession of the septum transversum, especially at its

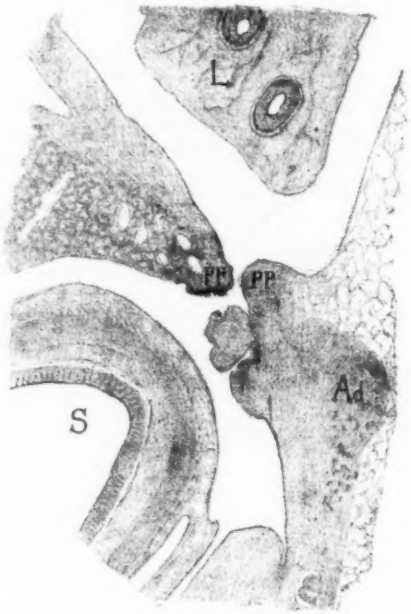

FIG. 43.—Section through the opening between the pleural and peritoneal cavities in the embryo 14 mm. long × 50 times; *s*, stomach; *l*, lung; *pp*, pleuro-peritoneal membrane; *ad*, adrenal.

dorsal end, the evagination of the cœlom containing the liver and stomach is complete, throwing them into the general peritoneal cavity.

Figs. 39, 40 and 41 are sections through the pleuro-peri-

FIG. 44.—Sagittal section through the body of the embryo 16 mm. long. No. XLIII × 10 times; *9*, ninth rib.

cardial and pleuro-peritoneal membranes of Embryo CIX, Fig. 38. They give the relation of the pleuro-pericardial and pleuro-peritoneal membranes to the surrounding structures. The heart is now in its permanent location in the thorax and the liver is in the abdominal cavity. The septum transversum with its extension, the pleuro-peritoneal membrane, stretches across the body from the tips of the embryonic ribs. But in the thorax lie the lungs, and their further growth into the lateral walls of the embryo and septum transversum will make them encircle the heart, thereby enlarging the pleuro-pericardial membranes and changing position of the phrenic nerves.

After the heart, lungs, liver and stomach are located in their permanent positions the pleuro-peritoneal membrane grows rapidly and soon closes the opening between the pleural and peritoneal cavities. Fig. 42 is from a section lateral to the opening showing the phrenic nerve throughout its greatest extent. In this specimen the marked growth is in the pleural cavity. Fig. 43 is from a section through the opening on a larger scale, including also the adrenal. A stage slightly more advanced is shown in Fig. 44. In this specimen, as in the one above, both pleural cavities communicate with the peritoneal. In Embryo LXXIV, Fig. 45, the pleuro-

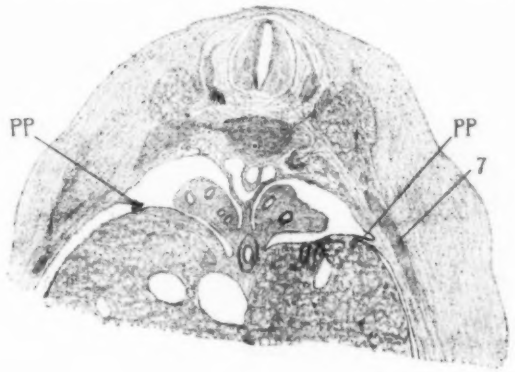

FIG. 45.—Transverse section through the embryo 14 mm. long. No. LXXIV × 10 times; *7*, seventh rib. The pleuro-peritoneal membrane; *pp*, is incomplete on one side.

peritoneal membrane is complete on the right side and incomplete on the left side. The reconstruction of this embryo shows that the opening is very large and extends from the seventh rib towards the tail. It may be an instance of retarded development, because in embryos 19 mm. long the membranes are as a rule complete on both sides of the body.

To what extent the permanent diaphragm is formed from the pleuro-peritoneal membrane it is difficult to determine. Undoubtedly the portion of the diaphragm on the caudal and dorsal sides of the pleuro-pericardial membrane is formed from the pleuro-peritoneal membrane. That portion of the diaphragm on the cephalic side is formed from the septum transversum. But the diaphragm is greatly extended on the lateral sides of the heart after the embryo is 20 mm. long by the extension of the pleural cavities around it. It appears from the models that this portion of the diaphragm is also formed directly from the periphery of the septum transversum.

OBSERVATIONS ON THE PECTORALIS MAJOR MUSCLE IN MAN.

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The Adult Muscle.

The peculiar twist in the sternocostal portion of the pectoralis major muscle is described in the various text-books on human anatomy. In general, the descriptions would indicate that the posterior layer of the tendon of insertion is formed in such a manner that its highest fibres have the lowest origin on the thorax, and the lower the fibres at the insertion the higher their origin on the thorax. There must thus be a crossing of fibres. This crossing is generally represented as taking place at or near the concave portion of the lower or axillary border of the muscle. I have found many anatomies incorrect or very incomplete in their description of the formation of the posterior layer of the tendon of insertion as well as the direction taken by the remaining sternocostal fibres, which go to the anterior layer of the tendon. These descriptions correspond fairly well with the direction the fibres appear to take when one examines the muscle superficially.

I have examined carefully twelve muscles to ascertain the direction of the fibres which form the apparent twisting. For this purpose specimens were taken from the dissecting room, from bodies embalmed with the carbolic acid mixture.[1] The muscles were placed in equal parts of glycerine, water and nitric acid for 24 to 48 hours. In most of the specimens thus treated the direction of the fibres was easily obtained as the connective-tissue elements were partially disintegrated and easily torn.

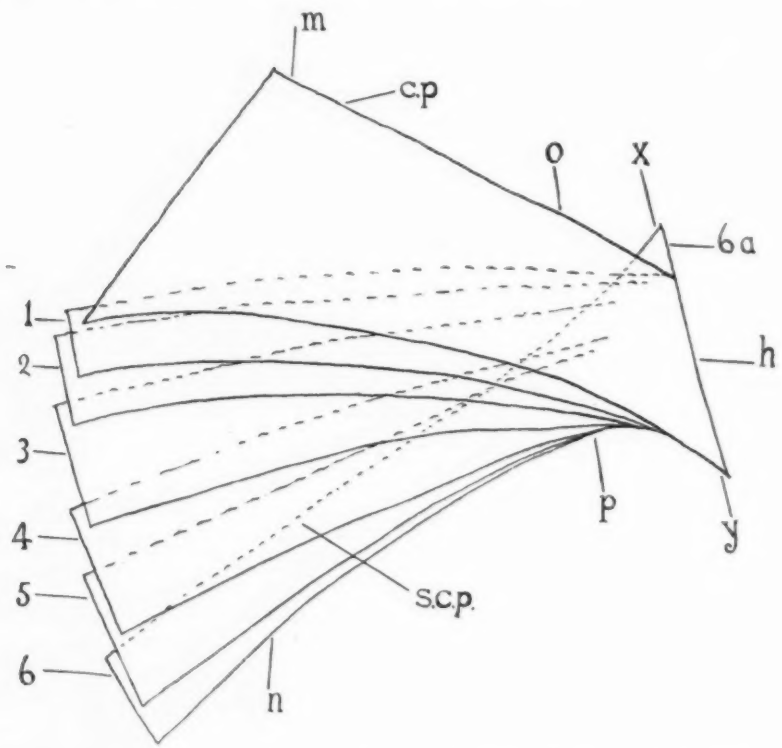

Fig. 1.—Diagram of an adult pectoralis major muscle. *c p*, clavicular portion; *s c p*, sternocostal portion; 1, 2, 3, 4, 5, 6, are overlapping bundles of fibres of the same; 6 *a*, portion of the posterior layer of the tendon of insertion coming from 6; *h*, humeral end of the muscle.

My dissections have shown in every case, (1) that the lowest fibres of origin go to the lowest end of the posterior layer of the tendon of insertion (Figs. 1 and 2), (2) that there is no crossing of fibres forming this posterior layer, and (3) that a peculiar fan-like arrangement of the bundles of fibres in the whole sternocostal portion is present (Figs. 1 and 2).

After the maceration, I found the muscle had a tendency

[1] F. P. Mall, The Preservation of Anatomical Material for Dissection, Anat. Anz., Bd. xi, p. 769, 1896.

to split into several overlapping bundles (Figs. 1 and 2; 1, 2, 3, 4, 5, 6). The number and size varies in different muscles. It will be seen from the diagram (Figs. 1 and 2) that the overlapping is more and more marked toward the humeral insertion.

The clavicular portion and upper five bundles form the anterior layer, and the sixth bundle the posterior layer, of the tendon of insertion. The lower fibres in each bundle, which are the superficial overlapping ones, reach to the lower end of the tendon, while the upper, deeper ones are more and more overlapped and pass to the upper edge or near to the upper edge of the tendon. Each bundle, as it approaches the tendon of insertion, spreads out and becomes thinner.

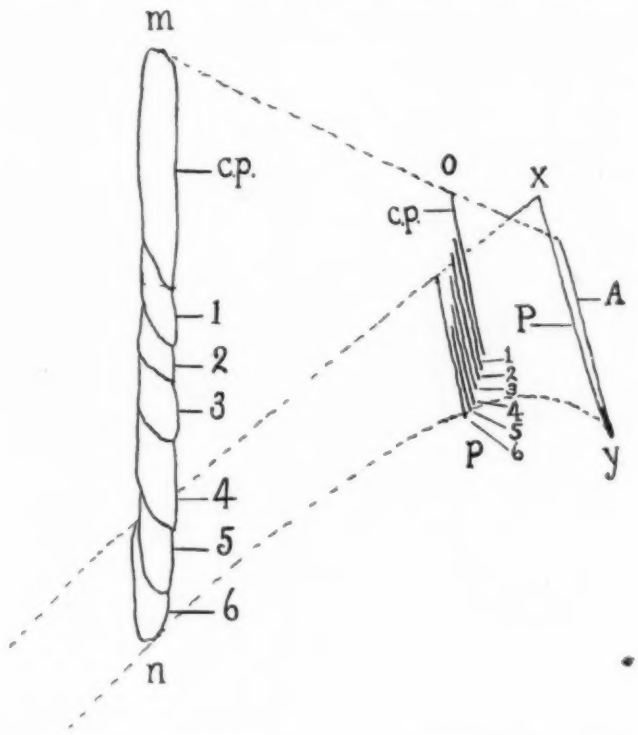

FIG. 2.—Diagram of cross-sections of the muscle taken at *m n*; *o p*; and *xy*, in (Fig. 1). Numbers and letters remain as Fig. 1. *A*, anterior layer of tendon; *P*, posterior layer.

The distance to which the muscle fibres go outward toward the humerus decreases from above downward and thus aids in keeping the distal end of the muscle thin.

The posterior layer of the tendon is continuous with bundle 6 (Figs. 1 and 2). It gradually spreads out and becomes thinner on approaching the humerus. As in the other bundles, its lower fibres reach the lower and its upper fibres the upper border of the tendon. The size of this bundle varies greatly, especially in the amount of overlapping toward the origin. Most of its fibres constitute the abdominal portion into which the muscle is sometimes divided. The accessory bundles of muscle having, as a rule, costal origin and which lie beneath the main muscle, are inserted into this posterior layer.

DEVELOPMENT.

I have attempted to trace the development of the muscle in a series of human embryos and to explain the origin of the peculiar arrangement of its fibres. For this purpose I have studied the muscle carefully in embryos varying in length from 9 to 40 mm. The first indication of the muscle I have been able to note was in an embryo of 9 mm. in length. In an embryo of 40 mm. the adult form is present. Reconstructions of the younger and dissections of the older embryos were made to study them.

In a human embryo measuring 9 mm. in length (No. CLXIII),[2] the pectoralis major and minor muscles are represented by a mass of closely packed cells without sharp limits. As there are no muscle fibres in this tissue I shall call it pre-muscle tissue. The other muscles of the arm and shoulder girdle are also represented more or less clearly by this pre-muscle tissue. There are, however, muscle fibres in the muscle-plate system. Here the muscle plates have fused into a continuous column and in the costal region extend along the intercostal spaces, partially surrounding the ribs and fuse together beyond their tips into a ventral plate. This muscle-plate system contains fibres, is farther advanced

[2] The numbers here given correspond with those in the catalogue of the collection of human embryos in the Anatomical Laboratory of the Johns Hopkins University.

and has a different appearance from the premuscle tissue, which is lateral to it and in the arm. In Fig. 3, which is from a wax reconstruction of the right arm region of this embryo, the costal portion of the muscle-plate system is seen (*m.pl.s*). Lateral to this is the lateral premuscle mass (*l.pm*). At the level of the first rib (*cI.*) the pectoral premuscle mass (*p.pm*) leaves the lateral to join the general arm premuscle sheath (*a.pm.*) along the ventral side of the proximal half of the condensed tissue which represents the humerus. The proximal end of the humerus lies opposite the interval between the fifth and sixth intervertebral disks (*dVc, dVIc*), the distal end opposite the first rib (*cI.*). The tion into masses, such as the pectoral, latissimus dorsi and levator scapulæ and serratus anterior. It is impossible for me in the case of the pectoral mass to determine how far caudally into the lateral premuscle tissue it extends, or just where to draw the line between it and the neck premuscle mass. Its humeral end is lost in the general arm premuscle tissue. Its location and correspondence with the muscle in the next stage and its nerve supply lead me to believe this to be the pectoral mass.

The pectoral premuscle mass is supplied by three nerves, from the brachial plexus, the fibres of which come from the *VI*, *VII* and *VIII* cervical and *I* thoracic nerves. It will

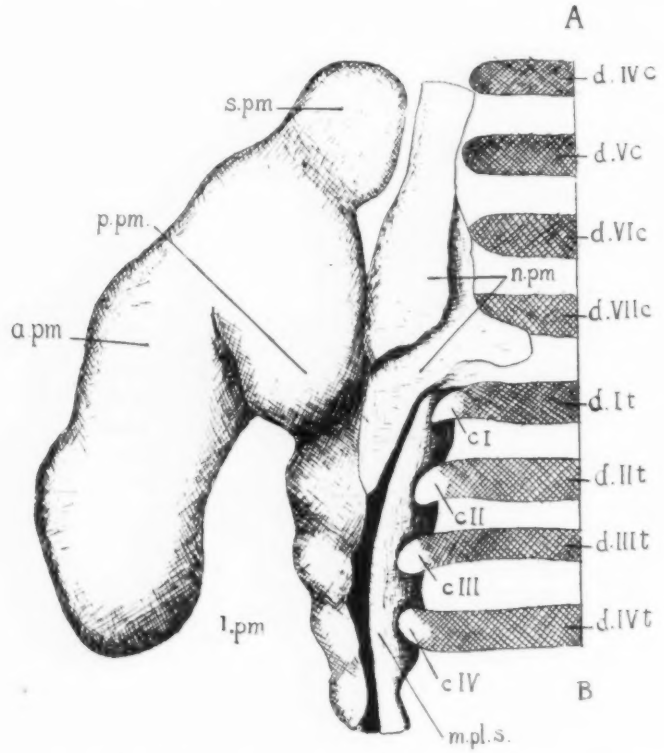

FIG. 3.—Ventral view of a wax reconstruction of the arm region of a human embryo measuring 9 mm. in length (No. CLXIII). Enlarged 50 times. *AB*, median line; *c* I, *c* II, *c* III, *c* IV, ribs one, two, three and four; *d* IV *c*, *d* V *c*, *d* VI *c*, *d* VII *c*, fourth, fifth, sixth and seventh cervical intervertebral disks; *a. pm*, premuscle mass ensheathing the arm; *l. pm*, lateral premuscle mass; *p. pm*, pectoral premuscle mass; *s. pm*, scapular premuscle mass.

scapula lies imbedded in the scapular premuscle tissue (*s. pm*). The clavicle is not present at this stage. The intervertebral disks are of condensed or closely packed cellular tissue (*d IVc*, etc., to *d IVt*). The ribs are of condensed tissue and project ventrad from the adjoining parts of the intervertebral disks and vertebral bows.

It is very difficult to determine the exact limits of the premuscle tissue; in a few places it is very sharply marked off from the surrounding mesenchyma as at the ventral end of the neck premuscle mass. The entire arm between the central skeletal core and the integument is filled with this tissue. At the root of the arm there are signs of a separa- be seen at this stage that the pectoral mass is mostly cervical and lies in the region of its nerve supply.

The fibres of the brachial plexus are directed laterally and have scarcely any caudal inclination.

In an embryo measuring 11 mm. in length (No. CIX),[3] there is great advance in the musculature of the arm. Many of the arm muscles, especially the proximal ones, can be

[3] Mall, (F.). The value of Embryological Specimens, Maryland Med. Journal, October 29, 1898. A Contribution to the Study of the Pathology of Early Human Embryos. Contributions to the Science of Medicine, dedicated to William H. Welch, Johns Hopkins Hospital Reports, vol. ix, 1900.

recognized. Instead of premuscle tissue we have distinct fibrillation.

The pectoral muscle mass extends from the region lateral to the ends of the first three ribs cephalolaterad to the cephalic border of the humerus. Its cephalic portion is closely associated with the medial end of the clavicle (Figs. 4 and 5, *cp.*). There is no definite attachment of the muscle to the ribs. The pectoralis major and minor are closely united. The latter is indicated by a bulging toward the coracoid process (*p.min.*, Figs. 4 and 5). I have with difficulty traced the general course of the fibres in the major portion of the mass, as will be seen in Fig. 5. The fibres from the clavicle do not appear to overlap the sternocostal fibres but occupy the proximal part of the insertion, while the sternocostal fibres occupy the distal. See Fig. 6, which is a diagram of the relation of these fibres close to their insertion into the humerus.

It is also worthy of note that the pectoralis muscle has extended caudally to the level of the tip of the third rib.

In an embryo measuring 16 mm. in length (No. XLIII),[1] the two pectoral muscles are entirely separate. The pectoralis major muscle assumes much more the adult form than in the previous stage. The entire arm has migrated caudally and with it the pectoralis major muscle. It now extends to the sixth rib (Fig. 7, *cVI.*). The clavicle has extended to the tip of the first rib, where it joins the cephalic end of the sternal anlage (*st.*, Fig. 7). The clavicular portion of the muscles is carried with the clavicle toward the median line. The humeral end of its fibres are seen to overlap the sternocostal fibres near the humerus (Figs. 7 and 8). There is a distinct gap between the clavicular portion (Fig. 7, *cp.*) and the sternocostal portion (Fig. 7, *scp.*) near their origins, The fibres of the sternocostal portion present a slight tendency to separate into bundles in which their is an overlapping of the deep portion of the lower by the superficial portion of the upper ones. This is more marked toward the insertion, as will be seen in Fig. 8, where the overlapping is quite complete. I have not been able to make out at this stage anything which corresponds to the deep or posterior tendon and, as will be seen later, it probably does not exist at this stage.

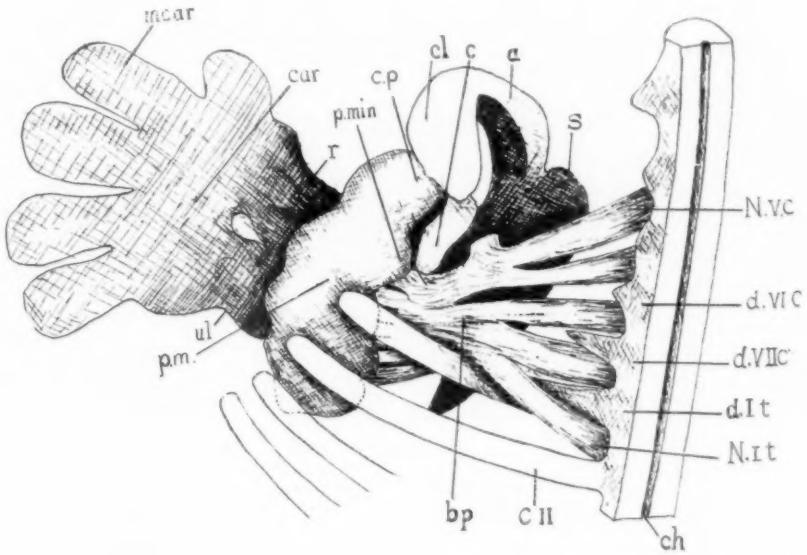

FIG. 4.—Median view of a wax reconstruction of the arm region of a human embryo measuring 11 mm. in length (No. CIX). Enlarged 30 times. *A*, acromion; *c* II, second rib; *c*, coracoid process; *car*, carpus; *c p*, clavicular portion of the pectoralis major; *cl*, clavicle; *ch*, chorda dorsalis split in the median line; *d* VI *c*, *d* VII *c*, sixth and seventh cervical intervertebral disks; *d* I *t*, first thoracic intervertebral disk, from which the first rib is seen arising; *mcar*, metacarpus; *p. m*, pectoralis major muscle; *p. min*, pectoralis minor bulging toward the coracoid process; *n*,V *c*, fifth cervical nerve going to join the brachial plexus; *bp*, brachial plexus; *r*, radius; *ul*, ulna; *s*, scapula.

Figures 4 and 5 are from a wax reconstruction of the right arm region of this embryo. All muscles but the pectorals are omitted.

The pectoral muscle mass is supplied by four branches of the brachial plexus, two from the outer and two from the inner cord, the fibres of which can be traced to the *VI*, *VII* and *VIII* cervical and *I* thoracic nerves.

It is of special note at this stage, that the larger portion of the muscle lies above the first rib, reaching about to the level of the fifth cervical intervertebral disk; that there is no overlapping of its fibres; and that the clavicle only reaches about one-half the distance from the acromion to the first rib.

[1] Mall, (F). Development of the Human Cœlom, Jour. of Morph., vol. xii, No. 2. Development of the Internal Mammary and Deep Epigastric Arteries in Man, Johns Hopkins Hospital Bulletin, Nos. 90-91, 1898. Development of the Ventral Abdominal Walls in Man, Jour. of Morph., vol. xiv, No. 2, 1898.

The nerve supply is as in the adult.

Embryo No. XXII,[5] measuring 20 mm. in length, shows about the same condition as in Embryo No. XLIII. The separation of the sternocostal portion into various bundles is especially well marked. They have no relation to the ribs so far as the number and position is concerned.

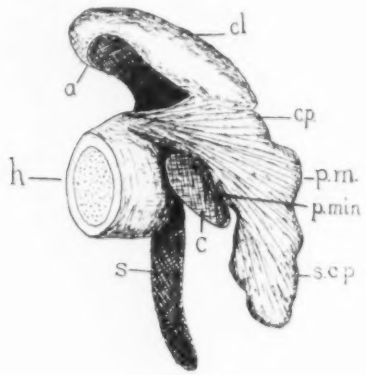

FIG. 5.—Ventral view of a portion of the model shown in Fig. 4, showing the pectoral muscle mass and its relations to the scapula, clavicle and humerus. *A*, acromion; *c*, coracoid process; *cl*, clavicle; *h*, humerus; *p. m*, pectoral muscle mass; *c p*, clavicular portion; *s c p*, sternocostal portion; *p. min*, pectoralis minor bulging; *s*, scapula.

In an embryo 32 mm. in length (No. CXXIX),[6] we find that the posterior layer of the tendon of insertion has made its appearance (Fig. 9). The fibres which go to this tendon come from the most caudal portion of the muscle. This posterior layer is about one-fourth the width of the anterior layer of the tendon of insertion. The embryo was studied with a dissecting microscope and so far I could determine

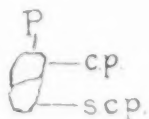

Fig 6.—Diagram of a cross-section of the pectoralis major fibres near their humeral insertion. Enlarged 50 times. *P*, proximal end of the same; *c p*, clavicular fibres; *s c p*, sternocostal fibres.

the arrangement of its fibres was otherwise similar to the adult.

In an embryo 36 mm. in length (No. XC), we find the posterior layer of the tendon of insertion nearly three-fourths the length of the anterior (Fig. 10). Otherwise the muscle appears to be much as in the adult. The pectoral region was studied with a dissecting microscope.

[5] Mall, Maryland Medical Jour., October 29, 1898, Ibid., Jour. Morph., vol. xiv, No. 2, 1898. Ibid., Johns Hopkins Hospital Reports, vol. ix, 1900.

[6] Mall, Contributions to the Science of Medicine, dedicated to William H. Welch, Baltimore, 1900, Johns Hopkins Hospital Reports, vol. ix, 1900.

In an embryo of 40 mm. in length the posterior layer of the tendon exceeds the anterior in width, and the muscle presents the adult form.

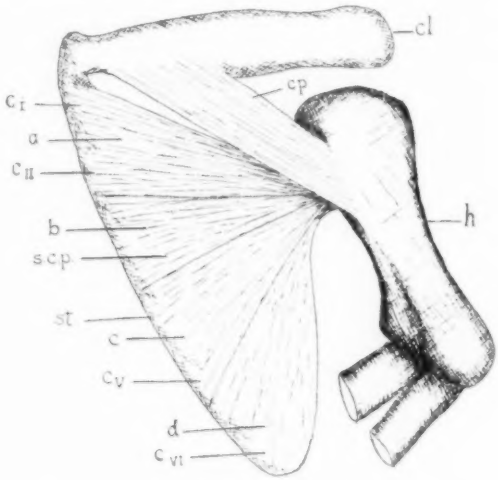

FIG. 7.—Ventral view of the pectoralis major muscle in an embryo measuring 16 mm. in length (No. XLIII), taken from a wax reconstruction of the arm region of the same. Enlarged 30 times. *S c p*, sternocostal portion, various artificial divisions of which *a*, *b*, *c*, *d*, are shown near their insertion in Fig. 8; *c* I, *c* II, *c* V, *c* VI, ends of first, second, fifth and sixth ribs, which, with the third and fourth join together to form the left half of the pectoralis major muscle; *h*, humerus, *p. m*, pectoral muscle mass; *s c p*, sternocostal portion; *s*, body of the scapula; *st*, sternum; *c p*, clavicular portion; *cl*, clavicle; *h*, humerus.

SUMMARY.

It is thus seen that the pectoralis major muscle arises in common with the minor from a premuscle tissue which is

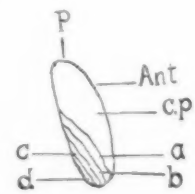

FIG. 8.—Diagram of cross-section of the pectoralis major muscle seen in Fig. 7, near its insertion into the humerus. Enlarged 30 times. *P*, proximal; *ant*, ventral surface; *c p*, clavicular portion; *a*, *b*, *c*, approximate position of the corresponding muscle bundles of Fig. 7.

located for the most part above the first rib. It gradually migrates or shifts to the costal region, as has already been noted by Dr. Mall.[7] During the course of this migration it splits into bundles. The clavicular portion is the first to split off. Later the sternocostal portion splits into the major

[7] Mall, Development of the Ventral Abdominal Walls in Man. Jour. of Morph., vol. xiv, No. 2, 1898.

and minor. The major becomes arranged into a series of overlapping bundles. As we have seen, the clavicular portion is the upper and most superficial. During the migration the overlapping of the sternocostal bundles is such that superficial fibres of each bundle have descended farther than the deeper, owing perhaps to the greater friction of the

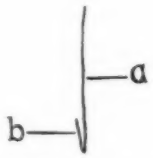

FIG. 9.—Diagram of the insertion of the pectoralis major muscle in an embryo 30 mm. in length (No. CXXIX). Enlarged 16 times. *A*, anterior layer of the tendon; *b*, posterior layer.

latter against the chest wall or to their earlier attachment. The lower bundle seems to be the last to be differentiated, and its tendon, the posterior layer of the tendon of insertion, appears to gradually spread out toward the proximal end of the humerus after the superficial or anterior layer is well formed.

The early entrance of the nerves into the muscle while still in the cervical region explains the adult nerve supply.

EXPLANATION OF VARIETIES.

It would seem that in the conditions existing between an embryo of 9 and 11 mm. in length might be found a partial explanation of such varieties as absence of the sternocostal or clavicular portions and of the pectoralis minor with the sternocostal portion. We have here a condition in which

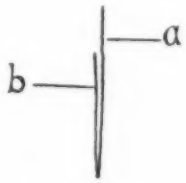

FIG. 10.—Diagram of the tendon near its insertion of the pectoralis major muscle of an embryo 36 mm. in length (No. XC). Enlarged 16 times. *A*, anterior layer; *b*, posterior layer.

the clavicle is absent and no attachment to the ribs exists. The subsequent attachment to one or the other might not occur and that portion of the muscle found wanting in the adult. With absence of the sternocostal portion would be associated that of the pectoralis minor owing to their early fusion. In the tendency to split into bundles, with the shifting of the muscle and fibres, the muscular bands which are often found as the costocoracoideus, sternalis, chondroepitrochlearis, etc., may have their origin.

ON THE BLOOD-VESSELS OF THE HUMAN LYMPHATIC GLAND.

BY W. J. CALVERT, M. D., U. S. A.,

Pathological Laboratory, Board of Health, Manila, P. I.

The lymphatic glands removed at autopsy from pest cadavers have enabled me, on account of the extreme congestion incidental to the disease and the reduction in the density of the nuclear elements of the gland, to follow in detail the course of the smaller vessels; the pathological changes referred to are not of sufficient degree to destroy the landmarks of the organ or to change the general relationship of the parts.

In an earlier communication I showed the course of the blood-vessels in the lymph follicle in the dog, and the present report is made because it demonstrates that the same arrangement is present in the human lymphatic gland.

The glands were fixed in Zenker's fluid, hardened in alcohol, sectioned in celloidin, stained in hæmatoxylin and eosin and mounted in balsam.

The illustrations show the origin and distribution of the follicular artery, the arrangement of the capillaries in the follicle and the origin of the veins. The course of the arteriæ and venæ lympho-glandulæ and the vessels of the cord have been illustrated.[1]

From the above illustrations and the many typical pictures seen in the slides the following scheme for the blood supply of the human lymphatic gland may be described: The arteriæ lympho-glandulæ enter the gland at the hilus, pass through the hilus stroma to enter the trabeculæ. In the trabeculæ arterial twigs are distributed to all portions of the gland. On reaching the portions of the gland near the proximal ends of the follicles small arteries arise which run in the lymphatic structure more or less parallel to the surface of the gland. These arteries give rise to the follicular artery (Figs. 1 and 2) and supply the adjacent portions of the pulp cords.

The follicular artery runs a straight course in or near

[1] The Blood-vessels of the Lymphatic Gland. By W. J. Calvert Anatomischer Anzeiger, xiii. Band, Nr. 6, 1897, p. 176.

the centre of the lymph cord of its particular follicle, to about the junction of the proximal with the middle third of the follicle. The follicular artery may give off branches to supply the adjacent portions of the cords. Near the centre of the follicle the artery breaks up into a number of small, straight, long capillaries which diverge to the periphery of the follicle. In some cases these capillaries branch, in others they do not.

Just beneath the periphery of the follicle these capillaries turn and branching form a rich plexus of capillaries which in turn unite to form small veins (Fig. 6). The plexus of capillaries in the follicle is continuous with a similar plexus in the cords.

The veins formed in the follicle run toward the proximal end of the follicle to join a rich plexus of veins.

The arteries supplying the cords are, as a rule, quite short, run in or near the centre of the cords and rapidly end in a rich capillary plexus near the surface of the cord. This plexus soon unites to form small veins which also run in or near the centre of the cords, but in a portion of the cord other than where the artery is found. The veins of the cord soon join veins from neighboring cords, through the anastomosis of the cords, to form larger veins which leave the cords to join the venæ lympho-glandulæ.

The veins from the follicles and adjacent portions of the cords unite to form a rich venous plexus, which lies within the lymphatic structure. This plexus may be considered to be the origin of the venæ lympho-glandulæ, which, like the arteries, run in the trabeculæ to leave the gland at the hilus.

The lymph channels are free from blood-vessels.

This arrangement of blood-vessels is also found in the lymph gland of the monkey.

NORMAL MENSTRUATION AND SOME OF THE FACTORS MODIFYING IT.

(PRELIMINARY NOTE.)

By Clelia Duel Mosher, A. M., M. D.,

Gynæcological Externe in the Johns Hopkins Hospital Dispensary.

The conclusions stated in this note are based on two kinds of data—clinical and experimental. The first consists of serial menstrual records of more than 300 women, collectively extending over more than 3000 menstrual periods. A large number of these records were made by the writer, month by month, when the women were under her personal observation in the Stanford University Gymnasium, and then were continued by the women themselves during holidays and vacations away from the university. The records were supplemented by preliminary statements, careful intermenstrual notes, and subsequent letters. The usual physical examination for admission to the gymnasium was made by the writer in many cases; to this was added an intimate knowledge of the conditions under which the women were living and working. Second, laboratory experimental data on the respiration,[1] urine, temperature, pulse and blood—blood pressure, blood counts, hemoglobin estimations and so on. Experimental work on the effects of clothing was also included. This work has been done in the physiological laboratories of the Stanford and the Johns Hopkins Universities, and in Dr. Kelly's laboratory. The first work was done in May, 1893, in California, has been continued as opportunity offered and is still in progress.

Some of the more important conclusions, which are based largely on the blood-pressure experiments and clinical data will be reported at this time.

Method.—Daily records of the blood pressure were made on 14 persons – 9 women and 5 men. The women were selected as representing normal conditions of menstrual health. The men were all healthy adults and 4 were athletic. An attempt was made to continue the records long enough to cover at least two periods of change in pressure; in some cases the observations extended over 19 days and some are still in progress. The blood-pressure records were made with the sphygmomanometer of Mosso. The tracings were taken daily at the same hour and under uniform conditions, perfect relaxation being secured and all variable factors excluded as far as possible.

Conclusions.—That a rhythmical fall of blood pressure, at definite intervals, occurs in both men and women. The daily records of the blood-pressure with the sphygmomanometer of Mosso on men and women under similar conditions of life and occupation give curves apparently indistinguishable in character. The fall in pressure in women occurs near or at the menstrual period. In all of the 14 series of records the fall of blood-pressure was gradual from the mean average pressure. This from day to day shows oscillations within rather definite limits. The maximum fall of pressure may extend over two or three days and the corresponding rise to the normal average pressure is gradual. There is usually a preliminary rise, above the normal average pressure; this occurs from 3 to 5 days before the onset of the main fall of pressure, which constitutes the principal feature of the rhythm. In every case there was a preliminary fall, abrupt and definite, but usually not so extensive as the main fall of pressure; this preliminary fall was followed by

[1] "Respiration in Women," Preliminary report as thesis for M. A. degree, Stanford University, May, 1894. Also paper presented at California Science Association, Jan. 3, 1896.

a return to the normal or higher pressure before the principal fall occurred. In 4 cases there was a distinct rise above normal after the main fall of pressure before the return to the normal daily oscillations. These variations were not peculiar to either sex.

A curve constructed on the subjective observations of the sense of well being, shows ups and downs corresponding to the marked variations in pressure; the sense of maximum efficiency of the individual corresponding to the time when the pressure is high, and lessened efficiency to the periods of low pressure. The observations were carried on independently of each other. In no case was the change sufficient to incapacitate the individual. The time of low pressure appears to be, in both sexes, a period of increased susceptibility. If symptoms of any kind are shown they are apt to be given by the point of least resistance. For example, if a man or woman having a tendency to digestive disturbances, the symptoms from the digestive tract are likely to occur at the period of low blood pressure; or when a slight chronic catarrh exists, as so frequently happens in this climate, there may be marked increase of symptoms from the respiratory tract.

In women the fall in blood pressure most frequently occurs before the menstrual flow, the maximum fall being coincident with the onset of the flow; there is a gradual return to the normal mean pressure by the time the menstruation ceases. Occasionally the fall occurred during the flow.

While true dysmenorrhœa is far too frequent, much of the so-called menstrual suffering is not dysmenorrhœa but simply coincident functional disturbances in other organs, induced, possibly, by the favoring conditions of a lowered general blood pressure occurring near or at the time of menstruation. (Goodman's restricted definition of menstruation is adhered to—"A periodic sanguineous defluxion from the genital tract.")

When the attention is of necessity directed to so obvious a process as the menstrual flow, untrained women, especially if without absorbing occupation, naturally refer their lessened sense of well being and diminished sense of efficiency, which may accompany the lowered general blood pressure occurring near or at the menstrual flow, to the function of menstruation. When we remember how firmly fixed is the tradition that a woman must suffer and be incapacitated by this normal physiological function, it is readily understood how many women would call the depression due to lowered blood pressure, menstrual suffering.

All statistics, however extensive or carefully taken, are likely to exaggerate the percentage of women suffering from dysmenorrhœa, because the errors just mentioned are so difficult to eliminate.

The conception that functional disturbances in other organs are considered and recorded as dysmenorrhœa was first derived from the study of the clinical data and later strengthened by the blood-pressure experiments supplemented by the notes of the persons studied.

The conclusions of this paper would have been impossible had my clinical data consisted merely of isolated statements based on the general impressions, as to their own conditions, of individual women filling out a single menstrual record, and without a personal acquaintance with, and an intimate knowledge of, the habits of life and conditions of work of the women studied.

Although space forbids detailed acknowledgements at this time, I wish to state my obligations for many favors received at Stanford University in the earlier work; to Dr. Howell and his associates, Dr. Dawson and Dr. Erlanger of the Physiological Department of the Johns Hopkins University; to Dr. Kelly's liberality and generous encouragement which have made possible all of the later work. The intelligent cooperation of my former students and many friends and of the men and women who have recently given and are giving so much of their valuable time, has made this work possible.

RETROJECTION OF BILE INTO THE PANCREAS, A CAUSE OF ACUTE HEMORRHAGIC PANCREATITIS.

By W. S. Halsted, M. D.

Mr. T., aged 48, a corpulent and robust looking man, had been subject to attacks of "indigestion," attended with pain in the epigastrium and a feeling of distention, for several years. These attacks would sometimes incapacitate him for business. He had a severe attack of this kind last Christmastide. He described also attacks of "vertigo," which had laid him up for 8 or 10 days every spring, with perhaps one exception, for the past ten years. At the end of April, 1901, he arrived in Baltimore after a hard railroad trip of about 8 days. On the way, suffering with indigestion, he bought a two-ounce package of bicarbonate of soda, half of which he consumed. After luncheon on the day of his arrival he was seized quite suddenly with a severe pain in the abdomen; he was nauseated and expressed his desire to be relieved of the "gas in the stomach." His physician administered calomel, and later nux vomica and carminatives. For 24 hours he was relieved; then, after eating buckwheat cakes, the pain returned. Occasionally drinking large quantities of water, he forced himself with difficulty to vomit. He suffered almost constantly more or less pain for a week, but took his meals regularly and slept about as well as usual. About noon on the 5th of May, the pain became very severe; morphia administered hypodermically three times during the afternoon, ½ grain in all, did not give much relief.

Inhalations of chloroform had to be given. At 9 p. m. I was asked to see him by his attending physicians. As I entered his bedroom, he was walking about in his pajamas, excited and nervous, and his teeth chattering; he seemed to be in great pain. His pulse was full and regular, 92 the first count and 87 the second. When I attempted to examine him he made an effort to keep quiet but in a moment had to spring up again. He was sensitive to pressure over the epigastrium, but not exquisitely, the point of greatest tenderness being a little above and, I thought, to the right of the umbilicus. He was somewhat cyanosed. My attention was called to the cyanosis by the print of my fingers on his abdominal wall. His condition was so good that I thought, with his physicians, he was probably suffering from gall stones. He refused to go to the hospital. Hot baths during the night relieved him, I am told, for the time, but he had to be chloroformed frequently. In the morning he was anxious to go to the hospital and was operated upon immediately after his arrival, about 11 a. m.

Operation.—The cyanosis of the patient was much more striking as he was laid on the operating table, and he vomited as he was being anæsthetized. The abdomen was not distended, but the panniculus was very deep. On opening the belly through the middle line blood-stained fluid escaped and at once it was noticed that the omentum showed abundant fat necroses; these necroses were to be seen in the subperitoneal fat, in the mesentery, along the lesser and greater curvatures of the stomach, etc. In order to explore more fully the pancreas and to make sure that a certain hemorrhage in the wall of the stomach, near the pyloric end, had not produced any serious lesion, the omental bursa was rapidly opened. Nothing that could be designated as a tumor mass was made out; the entire region of the pancreas could be palpated. The tissues over the pancreas were slightly infiltrated with blood-stained serum. The common bile duct, however, was distended to the size, perhaps, of an index finger. The presence of a stone in the diverticulum was of course suspected, and a careful though hurried search made, but none could be felt; the fluid in the abdominal cavity was rapidly sponged out and a gauze pack placed over the head of the pancreas. The abdomen was then closed. The patient died within 23 hours.

Pain, vomiting, distention of the abdomen, sometimes an elastic swelling in the region of the pancreas, fluid in the peritoneal cavity, pulse 140 to 160 or higher, cyanosis, collapse—these are the symptoms which the surgeon calls to mind when he pictures to himself a case of acute hemorrhagic pancreatitis, and hence it is that this disease has so many times been considered acute intestinal obstruction. My patient was strong, restless and walking about the room, not collapsed; his pulse was 92 the first count, 87 the second; the abdomen was not only not distended but, according to the patient, had greatly diminished in size during the few weeks preceding this illness; the reduction in the size of his waist, as evidenced by the considerable space between the band of his trowsers and his abdominal wall, was a matter which apparently gave him some concern, for he referred to it more than once. Vomiting, if present, was so inconspicuous a symptom that it had not been noticed; the patient had perhaps 3 or 4 times tickled his pharynx because he thought it relieved him to gag and bring up a little mucus from his stomach. When I saw him about 13 hours before the operation and again an hour before it, pain in the epigastrium and slight cyanosis were his only symptoms. But the pain must have been intense and seemed greater than I had ever seen it in cases of gall stone. I had the misgiving that I was in the presence of an unfamiliar affection and was prepared for a surprise when I opened the abdomen; and yet acute pancreatitis did not occur to me, my conception of the clinical picture was so different. But I shall not soon forget this case; the excruciating pain in the epigastrium and the cyanosis; altogether, a clinical picture different from anything that I could recall. To save my colleagues and students the humiliation of making the same mistake, I have thought that it might be well to represent graphically the only sign which this obscure case presented, the white print of fingertips in a slightly cyanosed field just over the site of greatest pain. Attacks of acute hemorrhagic pancreatitis, mild and severe, are probably much more common than is generally supposed, and I am sure that the clinical picture is sufficiently definite to be easily recognized by the general practitioner.

The autopsy was most carefully made by Dr. Opie, whose description of it will follow. The stone, which I could not find in my hurried search at the operation, was almost too minute to have been detected under the circumstances, and even at the autopsy it was only after prolonged handling and probing of the papilla itself outside of the body that the presence of a stone was determined. Opie has found that gall stones have been present in the majority of the more recently reported cases of acute hemorrhagic pancreatitis. In some instances they were, undoubtedly, not carefully searched for, in a few they may have been overlooked and in others they may have passed the papilla, having been arrested in the diverticulum long enough to produce the lesion in the pancreas. If it is true, as this case and Opie's experiments recorded below prove almost beyond question, that acute hemorrhagic pancreatitis may be caused by bile retrojected into the pancreatic duct, the inference that milder lesions and subacute and chronic changes may be produced in the pancreas by the mere presence of bile in its ducts is natural. The fact that the entire pancreas is not always or even usually involved, normal areas being found here and there among the hemorrhagic ones, makes it seem not unlikely that quite small patches may at times be affected and that the symptoms after very limited involvement might be overlooked or misinterpreted. Epigastric pain, rapid pulse, nausea, vomiting and possibly hematemesis coming on either soon or long after operations upon the common duct might in some instances be attributable to lesions in the pancreas.

The Mechanism.—The arrangement of the parts concerned

in the production of acute hemorrhagic pancreatitis reminds me of the hydraulic ram in its primitive form. The ductus choledochus is the feed pipe, the pancreatic duct the delivery pipe and the calculus the ball valve or stop cock. Although I know of no experiment to determine the force with which bile may be ejected from the gall bladder, it is conceivable that the sudden and complete interruption of the flow of bile during digestion by a calculus might give rise to a retrojection spurt of considerable volume and velocity. But whether this force is considerable or not, since the pancreatic juice and the bile are secreted at almost the same, quite low (29 mm. of water) pressure, it would probably be sufficient, as Dr. Opie will show, to drive the bile into the pancreatic duct under the proper conditions.

Why is pancreatitis hemorrhagica acuta such a rare disease?

1. That bile may be retrojected into the pancreatic duct, the stone must be (*a*) too small to occlude the pancreatic duct or interfere with the force of the jet and at the same time (*b*) too large to pass the papilla.

2. A narrow papillary orifice, such as we found in my case (a rare condition), would predispose to this affection, because many stones small enough to fulfill (*a*) the first condition are too small to fulfill (*b*) the second.

3. One calculus would be more likely to cause the pancreatitis than several, for other stones in this duct, unless very small, would weaken the force of the bile-spurt which drives the ball valve against the papillary orifice. I have elsewhere called attention to this fact.[1]

4. The gall bladder must perhaps be normal or nearly so; not thickened, shrunken or weakened by inflammation. Accordingly, one must have a calculus or calculi which have produced insignificant changes, if any, in the walls of the bladder.

5. The anomalies which Dr. Opie will consider protect a certain proportion of cases.

6. A predisposition may be necessary, as is given by adiposis and excessive use of alcohol.

Apropos of what I have said as to the possibility of mild attacks of hemorrhagic pancreatitis after gall stone operations, Dr. Finney has just told me the story of a most interesting and perhaps not wholly unique case. Four months ago he did a choledochotomy for 2 large soft stones in the common duct. The duct was enormously dilated, the gall bladder atrophied. The stones were almost as mushy as damp salt, and crumbled to pieces in the duct. The detritus was removed with extreme care and the duct afterwards repeatedly flushed with the physiological solution; notwithstanding this it seemed to Dr. Finney that some grains still remained in the duct. The incision into the common duct was sutured and the convalescence was entirely uneventful except for a trivial leakage of bile beginning about the 7th day p. o. A few days ago, when in robust health, the patient was seized with excruciating pains in the epigastrium, unlike any that he had ever experienced. Dr. Finney was telegraphed for promptly and reaching the patient in a few hours found him vomiting, collapsed, cyanosed and suffering pain so severe that morphia in large doses did not control it; the pulse was about 160, pressure over the pancreas was unendurable, the abdomen was distended. Acute pancreatitis was suspected, and operation, considering the collapsed condition of the patient, deemed inadvisable. The following day the patient was brought to the Johns Hopkins Hospital, his condition was greatly improved and 48 hours later he seemed perfectly well.

Is it not probable that in this case one of the fragments increased in size may have been responsible for the attack? Was the fragment passed? What were the lesions in this attack? Acute pancreatitis just beginning to be understood will probably soon become a household word.

Treatment.—We must learn to make the diagnosis promptly, and to distinguish gall stone attacks *per se* from those attended with pancreatic complications.

To search for and remove the stone in the diverticulum as soon as possible after the appearance of the first symptoms would be the correct procedure in some cases if the true nature of the attack could be recognized early enough. If this patient of mine had been operated upon and the stone removed at some time prior to the onset of his severe symptoms, perhaps at any time within the first seven or eight days of his illness, it seems probable that his life could have been saved. Without operation there was little if any hope for him, for the conditions responsible for the lesions would have persisted. It was evident at the operation that the common duct was obstructed but the patient's condition absolutely contraindicated prolonged search for the cause, which probably could only have been determined by opening the common duct or the duodenum, so minute was the calculus. Operation should not be undertaken upon cases in collapse, but the bloody fluid, probably highly toxic,[2] may be hastily evacuated by laparotomy (local anæsthesia) in cases too ill for radical operation.

Of 25 cases of acute hemorrhagic pancreatitis operated upon only two have recovered, a case operated upon by me eleven years ago[3] and Hahn's case recently reported.[4]

In his recent article Prof. Hahn expresses a desire to learn if the operation performed by me in the case which recovered was prolonged by the usual search for some cause of intestinal obstruction, and the hope that, in future, inoculations of culture media will be made from the blood-stained abdominal fluid. It gives me pleasure to be able to reply and to state that fat necrosis was at once observed, the diagnosis promptly made and the operation, therefore, probably a short one: drainage was not employed. This patient is alive and apparently well. In the second case, inocula-

[1] Halsted. Contributions to the Surgery of the Bile Passages. The Johns Hopkins Hospital Bulletin, January, 1900.

[2] Hahn. Deutsche Zeitschr. f. Chir. Bd. 85. Heft 1.

[3] Körte. Die Chirurgischen Krankheiten und die Verletzungen des Pankreas.

[4] Hahn, l. c.

tions from the bloody abdominal fluid were made, and with negative results.

It seems not improbable that, as Hahn states, the rapid evacuation of the bloody fluid in the abdominal cavity may in some cases be beneficial. Hahn believes that this fluid is highly toxic and perhaps infectious, and emphasizes the fact, exemplified by one of the cases which he reports, that large retroperitoneal extravasations of blood cause incomparably less disturbance than we see in these cases of hemorrhagic pancreatitis in which the loss of blood is insignificant. I had read Hahn's article only a few days prior to the operation upon this case and was acting upon his suggestion, but coming so quickly upon the dilated common duct I felt myself compelled to make a hurried search for the cause of the obstruction. I have little doubt that my operation hastened the death of the patient.

If a stone in Vater's diverticulum was the cause of the pancreatitis in my first case, the one that recovered after operation, we must conclude that it passed the papilla, probably during the attack, for it had produced no symptoms from the time of the operation, May, 1890, until June, 1895, when he was examined in the hospital by Dr. Bloodgood. I find that I misinformed Dr. Körte[6] when I wrote him that my recovered case had had a subsequent attack. The attack referred to occurred in another case, one of suppurative pancreatitis, operated upon and cured by my associate, Dr. Finney.

[6] Körte: Die Chirurgischen Krankheiten und die Verletzungen des Pankreas. Deutsche Chir. 1898, p. 171.

THE ETIOLOGY OF ACUTE HEMORRHAGIC PANCREATITIS.

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Pathological Report.

In many reported cases of hemorrhagic and of gangrenous pancreatitis symptoms of cholelithiasis have been associated with the fatal illness and at autopsy calculi have been found in the gall bladder or in the bile passages. In a recent article[1] I collected from the literature thirty-one cases of this character and described an additional instance. In eight of these cases, including the one which I reported, a gall stone was found at autopsy lodged near the orifice of the common bile duct or there was evidence that one had shortly before death occupied this position. Since the common bile duct and the duct of Wirsung unite to form the diverticulum of Vater before they enter the intestine, a calculus so located might occlude both ducts. In the greater number of these collected cases though calculi were found at autopsy, none were situated near the junction of the two ducts. Nevertheless since, as was pointed out, death with intense hemorrhagic inflammation of the gland has in several instances followed within forty-eight hours the onset of symptoms and a calculus has been found near the duodenal orifice of the common duct, it is readily conceivable that a stone temporarily lodged in the position indicated might produce grave alteration of the gland before its final expulsion into the duodenum. In seven of the thirty-one cases death followed the onset of symptoms, intense abdominal pain, vomiting and profound collapse, within forty-eight hours, and at autopsy the pancreas was the seat of hemorrhagic infiltration. In seventeen instances in which the fatal illness was of longer duration, seven days to four months, the pancreas was gangrenous and there was often evidence of previous hemorrhage. There can be little doubt that gangrenous pancreatitis is a late stage of the hemorrhagic lesion.

That acute pancreatic disease is frequently associated with cholelithiasis has been confirmed by cases reported since the preparation of the article referred to. The two conditions were present in three cases recently described by Lund,[2] in two by Bryant[3] and in one by Stockton and Williams,[4] by Struppler[5] and by Hahn.[6] The relative frequency with which acute pancreatitis is accompanied by cholelithiasis is difficult to estimate. In some cases the lesion has been diagnosed upon the operating table and, no autopsy being obtained, the condition of the bile passages has not been determined. In a very large proportion of the cases the autopsy report is so meagre that the presence or absence of gall stones is not evident. Lund records the relatively large number of six cases of acute pancreatitis, one suppurative, five hemorrhagic or hemorrhagic and gangrenous. Two of the five cases he describes as hemorrhagic peripancreatitis. In three of these five cases the gall bladder or the bile passages contained small calculi in large number, while in the remaining two no autopsy was obtained. In the two cases reported by Bryant hemorrhagic pancreatitis was associated with gall stones. In only one of the five cases of Hahn were gall stones present, but in one of his cases hemorrhagic infiltration of the gland followed a pistol shot wound and in another recovery followed operation. Gall stones were, therefore, present in six of eight cases with autopsy described by three writers who have recently reported more than one instance of the disease.

In view of the fact that in several instances a calculus has been found at autopsy so lodged as to occlude the pancreatic duct, there can be no doubt that the frequent association of the two conditions is the result of an etiological relationship. The common bile duct and the larger pancreatic duct lie side by side as they penetrate the wall of the duodenum and are often separated near their junction only by a thin mem-

[1] Opie. Amer. Jour. of the Med. Sciences, 1901, cxxi, p. 27.

[2] Lund. Boston Med. and Surg. Jour., 1900, cxliii, p. 543.

[3] Bryant. Lancet, 1900, ii, p. 1341.

[4] Stockton and Williams. Philadelphia Med. Jour., 1900, vi, p. 649.

[5] Struppler. Deutsche Arch. f. klin Med., 1900, lxix, p. 206.

[6] Hahn. Deutsche Zeitschr. f. Chir., 1900, lviii, p. 1.

branous septum, while before entering the duodenum at the summit of the bile papilla they unite to form a short channel, the diverticulum of Vater. From a study of the case previously reported it seemed not improbable that a calculus lodged in the common bile duct near its termination might cause partial occlusion of the pancreatic duct and subsequent changes in the pancreas as the result, possibly, of bacterial invasion. This case, as well as those recorded in the literature, afforded, however, no explanation of the pathogenesis of hemorrhagic inflammation. The autopsy recently performed upon the case described by Dr. Halsted has demonstrated a mechanism by which this lesion is produced.

Autopsy.—The body, which is still warm, is that of a large man with very abundant subcutaneous fat. The skin has a bluish cyanotic appearance. Passing downward from the right costal margin to a point 10 cm. from the symphysis pubis is a longitudinal incision, closed in great part by subcutaneous silver wire sutures. Crossing the epigastric region and meeting the first at right angles is a second incision. At their angle of junction the wound is unclosed for a short distance and gauze packed about by rubber protective passes into the abdominal cavity.

The peritoneal cavity contains a moderate excess of blood-stained serous fluid. The general peritoneal surface is smooth. Fat is present in very great amount in the omentum, in front of the peritoneum of the anterior abdominal wall below the umbilicus, in the mesentery, in the retroperitoneal tissue and as appendices epiploicæ upon the surface of the large intestine. Studding the fat in the various situations named and conspicuous upon its translucent surface are small usually round opaque white areas 2 to 3 mm. in diameter, often surrounded by a narrow zone of injection. They are superficially situated and extend usually less than 1 mm. below the surface. They are most abundant in the omentum and in the retroperitoneal fat adjacent to the pancreas. The gauze drain previously mentioned passes between the stomach and the transverse colon and lies in contact with the retroperitoneal fat immediately below the head of the pancreas. Here the tissue has a reddish-black discoloration.

The pancreas is represented by a blackish swollen mass extending from the descending part of the duodenum to the spleen. The fat in contact with its splenic end has a similar blackish color and is soft and friable. The pancreas is greatly increased in size, is irregularly cylindrical in shape and measures 5.2 cm. antero-posteriorly, 5.5 cm. from above down, and 16 cm. in length. The anterior surface is smooth and has an almost uniform black color in places with a reddish tint. On section the gland substance is found to be in great part transformed into black and reddish-black material. The head of the organ for a distance of 2.5 cm. from the duodenum is firm, gray yellow, with well marked lobulation, and has the appearance of the fresh normal pancreas. Tissue which is in immediate contact with this well preserved gland substance is soft and black in color, mottled here and there with small areas of dull red; gland lobulation is still very obscurely marked. The distal half of the organ shows a similar mottling of black and reddish areas with in places small islands of yellowish, relatively preserved tissue. The largest of these, which is of reddish-yellow color, gradually passing into the surrounding reddish-black, is 1.5 cm. in diameter and is situated near the middle of the body. At the splenic extremity is a slightly smaller mass of intact gland substance. On opening the splenic vein where it lies in contact with the pancreas the intima is found to have a mottled yellow, blackish and red appearance, due to changes in the underlying tissue. Occupying a portion of the lumen is a mixed red and yellow thrombus mass, firm in consistence and adherent to the intima.

The duodenum was opened and the common orifice of the bile and pancreatic ducts examined. The papilla is prominent but its orifice is of small size measuring 1 mm. in diameter. The common bile duct which near its termination is completely embedded in the substance of the pancreas is slightly distended. By very firm pressure on the gall bladder several drops of bile can be squeezed with difficulty into the duodenum. The gall bladder when opened is found to contain a moderate amount of viscid blackish bile; no concretions are present. The termination of the pancreatic duct, which is surrounded by the well preserved pancreatic substance in contact with the duodenum, was exposed by dissection and found to unite with the common bile duct 10 mm. from the summit of the bile papilla. A probe passed down the common duct was stopped 4 mm. from the latter point, and it was not possible to touch it with a second probe passed into the narrow orifice. Careful examination disclosed a small gray-white, very firm concretion 3 mm. in diameter, snugly filling the diverticulum of Vater from which it could not escape through the narrow duodenal orifice. The pancreatic duct, where it passes through the intact tissue of the head, is like the common duct stained bright green with bile.

The heart and lungs are apparently normal. The liver weighs 1350 grms. The surface is smooth and of yellowish color; upon the upper surface of the right lobe are conspicuous slightly depressed dull red areas which are irregular in shape, the larger about 2.5 cm. across. The cut surface of the organ has a bright yellow color, the periphery of the lobules being golden-yellow, the central part reddish. Corresponding to the superficial red areas the liver substance has a similar dull red appearance, the periphery of the lobules being marked by narrow yellow zones. Such altered tissue has at times an irregularly wedge-shaped outline and within it are found portal veins distended and plugged with red thrombus material. Following the vein in one of these areas toward the main portal trunk, the thrombus stops abruptly and near its end is of yellowish-white color, representing probably embolic material from the thrombosed splenic vein. The spleen is not enlarged and weighs 140 grms. The organ is flaccid but fairly firm in consistence.

The stomach contains a small amount of blackish semi-fluid material. The duodenum and remainder of the small intestine contain similar material. The kidneys, weighing

together 290 grms., appear to be normal, except for the presence of opaque yellow striations near the apices of the pyramids. The adrenals, the bladder, the seminal vesicles and the prostate are normal. Upon the intima of the aorta are a few slightly raised opaque yellow patches of small size. The urine contained in the bladder does not reduce Fehling's solution.

Microscopic examination of the pancreas.—A section passing through the line of demarcation between the intact parenchyma in the head of the gland and the adjacent necrotic tissue shows a very abrupt transition from the one to the other. On the one side the pancreatic tissue is well preserved, the secreting cells are normal in appearance and their basal zone stains deeply with hæmatoxylin, while islands of Langerhans are fairly abundant and appear to be normal. The loose interlobular areolar tissue is everywhere infiltrated with red-blood corpuscles; polynuclear leucocytes are present in large number and often form collections of considerable extent. Eosinophilic leucocytes are numerous and fibrin is abundant. Between the acini are a few polynuclear leucocytes. Within the margin of the intact tissue are several small areas where the parenchyma is undergoing necrosis. The secreting cells no longer stain with hæmatoxylin, but assume a homogeneous clear pink color with eosin; the nuclei which are still preserved are much smaller than those of the normal cells and unlike the latter are irregular and distorted and stain homogeneously. Small hemorrhages have taken place into the interacinar tissue of such an area, and polynuclear leucocytes are present in moderate number. Nearby in similarly localized areas the process is more advanced and the parenchymatous cells are replaced by formless material which staining faintly is mingled with a few nuclear fragments and is densely infiltrated with polynuclear leucocytes and red-blood corpuscles.

The transition from relatively normal parenchyma containing a few islands of necrosis to wholly necrotic tissue is very abrupt and is marked by a zone composed of nuclear fragments, polynuclear leucocytes, red-blood corpuscles and fibrin. That part of the section which corresponds to the black and reddish-black material seen macroscopically is necrotic, nuclei are no longer present and though the architecture of the gland is still obscurely definable both parenchyma and connective tissue stain only with eosin. At intervals in areas of varying extent the tissue has a dark brown discoloration due to the presence of brown pigmented material which appears to be changed blood.

Sections from the body and tail of the organ present the appearance described above. In the intact tissue of the tail well preserved islands of Langerhans are particularly numerous. In a section from the body nuclei still persist immediately about an artery, though the surrounding tissue is universally necrotic. Its endothelial cells are swollen and in places are almost cubical. In the media and adventitia, of which the vasa vasorum are preserved, polynuclear leucocytes are very numerous.

In sections stained by Weigert's method for the demonstration of fibrin was noted a histological detail inconspicuous by other methods. Capillary vessels in the living tissue near the margin of necrosis as well as in the immediately adjacent necrotic part have undergone hyaline thrombosis and form conspicuous deep blue, often branched, lines as though injected. Examination with high magnification demonstrates at times a close meshwork of fibrils in these vessels. In sections stained with hæmatoxylin and eosin their contents take a homogeneous bright pinkish-red stain and red-blood corpuscles are no longer seen, as in adjacent capillaries.

In sections stained for bacteria with methylene-blue, with gentian violet, and by Weigert's method, none were discovered.

Bacteriological examination.—Plate cultures in agar-agar were made at autopsy from the heart's blood, peritoneal cavity, pancreas (aërobic and anaërobic on hydrocele agar-agar), gall bladder, liver, spleen, and kidney. They were studied by Mr. V. H. Bassett to whom I am indebted for the following report. Cultures from the heart's blood, spleen, and gall bladder gave negative results. The anaërobic culture from the pancreas showed no growth after an incubation of seventy-two hours. The aërobic agar-agar plate from the pancreas contained at the end of twenty-four hours a single superficial colony of a pigment forming coccus whose cultural characters indicated that it was a contamination from the air. The streptococcus pyogenes and the staphylococcus epidermidis albus were isolated from the peritoneal cavity. The colon bacillus was present in cultures from the liver and kidney.

Anatomical diagnosis.—Cholelithiasis; calculus impacted in the diverticulum of Vater partially filling it and occluding its duodenal orifice. Acute hemorrhagic pancreatitis; disseminated abdominal fat necrosis. Partial thrombosis of the splenic vein; embolism and thrombosis of branches of the portal vein.

The preceding autopsy has disclosed a condition which explains, I believe, the pathogenesis of those cases of acute hemorrhagic and gangrenous pancreatitis which are associated with gall stones. The diverticulum of Vater was 10 mm. in length. Lodged at its apex, blocking its duodenal orifice, was a small calculus only 3 mm. in diameter, but too small to pass the narrow opening. Though it occluded the duodenal orifice of the diverticulum it was so small that the orifices of the common bile duct and pancreatic duct were unobstructed. The two ducts were therefore, converted into a continuous closed channel from which it was not possible for either bile or pancreatic juice to escape.

On dissecting the pancreatic duct where it passed through the unchanged parenchyma in contact with the duodenum it was found, like the bile duct, to be stained bright green with bile. Where, as in this case, the two ducts become a closed channel, the entrance of bile into the pancreas or of pancreatic juice into the bile passages would depend upon the relative pressure in the two ducts. The pressure at which bile and

pancreatic juice are secreted being small, any slight difference that might exist would be overcome by the gall bladder, a muscular organ which at intervals forces bile in considerable quantity along the common duct.

A small calculus only partially filling the ampulla of Vater can convert the two ducts into a continuous channel, while a larger stone might simultaneously obstruct the duodenal orifice of the diverticulum and the orifices of the two ducts which enter it, thus damming back bile and pancreatic juice upon their respective glands. In the present case, as previously mentioned, the diverticulum measured 10 mm. in length, the calculus 3 mm. in diameter. In many cases of hemorrhagic and gangrenous pancreatitis gall stones found in the gall bladder and bile passages at autopsy have been small and are often described as pea-sized. This statement is made in the reports of Day,[7] Cutler,[8] Kennan,[9] Simpson,[10] Chiari[11] (two cases), Smith,[12] Ehrich,[13] Fraenkel,[14] Körte,[15] Morian,[16] Rolleston,[17] Grawitz,[18] Opie,[19] Bryant[20] and Lund[21] (three cases).

Anatomical peculiarities of the diverticulum of Vater might favor or prevent the conversion of the two ducts into a closed channel. The description of the ampulla given by Sappey,[22] Testut,[23] Henle[24] and Quain[25] does not differ materially. It may be described as a somewhat conical cavity into whose base open the two ducts; the apex situated at the summit of the diverticulum is their common duodenal orifice. Its length varies from 6 to 7 mm. according to Testut, from 7 to 8 mm. according to Sappey. Occasionally the two ducts have no common channel, but open by separate orifices upon the summit of the bile papilla. Claude Bernard[26] described a variety of termination which has since been observed. The bile duct is prolonged as far as the mucosa of the duodenum, upon which it opens by a circular orifice. The terminal part of the pancreatic duct embraces the bile duct like a gutter and its orifice has the outline of a crescent. Where the ampulla is very short or the two ducts open separately into the duodenum it is evident that an impacted calculus could not render continuous the lumina of the two ducts.

[7] Day. Boston Med. and Surg. Jour., 1892, cxxvii, p. 569.
[8] Cutler. *Ibid.*, 1895, cxxxii, p. 354.
[9] Kennan. Brit. Med. Jour., 1896, ii, p. 1442.
[10] Simpson. Edinburgh Med. Jour., 1897, ii, p. 245.
[11] Chiari. Wiener Med. Wochensch., 1876, xxvi, p. 291; *Ibid.*, 1880, xxx, pp. 139, 164.
[12] Smith. Brit. Med. Jour., 1897, ii, p. 468.
[13] Ehrich. Beiträge z. klin. Chir., 1898, xx, p. 316.
[14] Fraenkel. Münch. med. Wochensch., 1896, xliii, pp. 813, 844.
[15] Körte. Arch. f. klin. Chir., 1894, xlviii, p. 721.
[16] Morian. Münch. med. Wochensch., 1899, lxvi, p. 348.
[17] Rolleston. Trans. Path. Soc. of London, 1893, xliv, p. 71.
[18] Grawitz. Münch. med. Wochensch., 1899, xlvii, p. 813.
[19] [20] [21] *Loc. cit.*
[22] Sappey. Traité d'anatomie descriptive. Paris, 1889.
[23] Testut. Traité d'anatomie humaine. Paris, 1894.
[24] Henle. Handbuch der Systematischen Anatomie des Menschen. Braunschweig, 1873.
[25] Quain. Elements of Anatomy. London, 1896.
[26] Quoted by Sappey.

I have recently examined the diverticulum of Vater in a small number of cases available. In three specimens (Nos. 3, 11 and 13) the ducts opened into the intestine by separate orifices. The following figures represent the length of the ampulla in these cases:

No. 1	5 *mm.*	No. 10	2.5 *mm.*
" 2	6 "	" 11	0 "
" 3	0 "	" 12	6.5 "
" 4	4 "	" 13	0 "
" 5	5 "	" 14	5.5 "
" 6	7 "	" 15	1.5 "
" 7	10 "	" 16	1 "
" 8	7 "	" 17	11 "
" 9	5.5 "		

No. 6 is from the case previously reported, No. 7 the one described in the present article. The figures are cited to show that the length of the so-called diverticulum varies considerably.

Another anatomical factor of considerable importance is the size of the duodenal orifice of the ampulla. Hyrtl[27] states that this opening is narrower than the lumen of the gall duct at any point or is at least less distensible so that gall stones often remain here impacted. In the autopsy described the opening measured only 1 mm. in diameter. In most instances it measured 2 to 2.5 mm.; in specimen No. 9 the diameter was 4 mm.

Experimental Study.

Hemorrhagic pancreatitis has been produced experimentally by the injection of a variety of irritating substances into the pancreas, but no attempt has been made to reproduce the lesion by the use of bile.

Thiroloix[28] injected several drops of deliquescent chloride of zinc into the duct of Wirsung in a dog. Death occurred suddenly after a short interval and the pancreas was represented by what appeared to be a blackish clot. Hlava[29] injected artificial gastric juice into the pancreatic duct. This fluid, containing hydrochloric acid in the proportion of 1 to 1000, caused death in three days; the pancreas was hyperæmic and in the fat of the omentum and of the mesentery were numerous foci of necroses. Death on the tenth day followed the injection of 5 cc. of artificial gastric juice with hydrochloric acid 4 to 1000; the pancreas was the seat of hemorrhagic infiltration and the omentum and mesentery contained foci of fat necrosis. He suggests that in human cases hyperacid gastric juice may be forced by antiperistaltic action of the intestine into the pancreatic duct, thus causing the condition. Hlava has produced a hemorrhagic lesion of the gland by injecting cultures of the bacillus coli communis, bacillus lactis aërogenes, and bacillus capsulatus of Friedländer, but thinks that the change is the result of the acid products of these organisms.

[27] Hyrtl. Handbuch der Topographischen Anatomie. Vienna, 1882.
[28] Thiroloix. Quoted by Carnot (see below).
[29] Hlava. Quoted by Flexner (see below).

Oser[30] records the injection of 4 cc. of $\frac{1}{10}$ normal sulphuric acid solution into the pancreatic duct of a dog. Death followed in twenty hours. In the duodenal part of the gland was a hemorrhagic area the size of a pea where the tissue was destroyed and its structure no longer recognizable. By the injection of the ferment, papaine (0.2 grms. in 30 cc. of water), into the duct of a dog, Carnot[31] caused the death of the animal in twenty-five hours; the pancreas was everywhere infiltrated with blood but there was no necrosis of fat. Smaller doses did not produce hemorrhagic lesions. The same writer produced hemorrhagic pancreatitis by the injection of the diphtheria toxine into the pancreatic duct of a rabbit. A suspension of the bacillus coli communis (12 cc.) caused a similar lesion fatal in twenty-four hours. Subsequent injections of the same organism caused inflammatory changes without hemorrhage.

More varied and successful experiments have been performed by Dr. Flexner[32] in this laboratory. In ten experiments performed upon dogs hydrochloric acid varying in strength in different instances from 0.5 to 2 per cent, and in amount from 3 to 8 cc., was injected into the pancreatic duct. In six instances there resulted hemorrhagic inflammation of the gland, accompanied in five by focal fat necroses. In three of these cases death followed the operation within twenty-four hours; in two the animals were killed. In the remaining experiments purulent or chronic interstitial inflammation resulted. Hemorrhagic lesions were produced in two dogs by the use of nitric acid (1 cc. of a 2 per cent solution and 5 cc. of a 1 per cent solution); in one, by the use of chromic acid (8 cc. of a 1 per cent solution). In a second series of experiments sodium hydroxide solution (2.5 to 5 cc. of solutions varying in strength from 1 per cent to 2 per cent) was employed. Hemorrhagic lesions resulted in three cases and were accompanied by fat necrosis in at least two. Suspensions of bacteria were used in a third series. Hemorrhagic inflammation was caused by the bacillus pyocyaneus and in three experiments by the bacillus diphtheriæ but was unaccompanied by definite fat necrosis. In two experiments the lesion followed the injection of 5 cc. of a 2 per cent solution of formalin into the duct and was associated with fat necrosis.

The experiments cited show that a variety of substances injected into the duct of the pancreas cause hemorrhagic inflammation. How far they can be used to explain the pathogenesis of human cases is doubtful. The suggestion of Hlava that gastric juice may be driven by antiperistaltic action of the intestine into the ducts is not supported by any evidence. The relation of hemorrhagic pancreatitis to bacterial invasion from the intestine has not been demonstrated. The condition observed in the autopsy described has suggested a mechanism by which an irritating substance can make its way into the organ. Can the hemorrhagic inflammation observed in human cases and produced in animals by means of various irritants be reproduced by the injection of bile into the pancreatic duct?

In the following experiments the duodenum of dogs was opened for a distance of several centimetres opposite the larger pancreatic duct. The blunt pointed nozzle of a syringe was inserted into the orifice of the duct and bile obtained from the same or from a second dog was injected into the organ. The operations were performed with the usual antiseptic precautions and the duodenal wound was closed by submucous mattress sutures. I desire to express my thanks to Mr. Bassett, Mr. Haskell and Mr. W. Marshall for assistance in the performance of these operations.

Experiment 1.—Into the larger pancreatic duct was injected 5 cc. of bile obtained from a second dog. The animal was killed seven days later. The peritoneal cavity contains a small amount of bloody fluid and the surface is injected. The large and several loops of the small intestine are firmly adherent to the splenic arm of the pancreas, and on separating them are exposed pockets containing very thick viscid fluid of dull red color. The walls of these pockets have in places the opaque white appearance of necrotic fat. The splenic part of the gland and the duodenal part, above the duodenal orifice of the main duct, is firm in consistence and both upon the surface and on section shows a mottling of opaque yellowish-white areas separated by deep hemorrhagic red. Over a considerable area at the junction of the duodenal and splenic parts of the gland the tissue is almost uniformly grayish-yellow and is in places softened and disintegrated. Cultures and coverslips from the peritoneal cavity and from the substance of the pancreas contain no bacteria. Microscopic examination of the splenic and duodenal parts of the gland show that wide areas of parenchyma including entire groups of lobules are necrotic and the secreting cells, which have a homogeneous hyaline appearance and are stained deeply with eosin, contain no nuclei. At the margin of such areas red-blood corpuscles and polynuclear leucocytes are present in great number and fibrin is abundant. In places the bodies of the secreting cells have been converted into formless detritus mingled with red-blood corpuscles and leucocytes. The interstitial tissue may be implicated in the general necrosis but often it has undergone very active proliferation and has in small part replaced the disintegrated acini. Islands of intact parenchyma still persist in places and are surrounded by newly-formed fibrous tissue, containing red-blood corpuscles and polynuclear leucocytes.

Experiment 2.—Bile (5 cc.) from a second dog was injected as before. The animal was killed at the end of five days. Lightly adherent to the part of the pancreas which is in contact with the duodenum are several loops of small intestine. In the omental fat are several opaque white areas of fat necrosis, while near the splenic extremity are several inconspicuous foci of a similar nature. In the duodenal part of the gland in the neighborhood of the orifice of the larger duct for a distance of 3.5 cm., there is extensive hemorrhagic infil-

[30] Oser. Die Erkrankungen des Pankreas. Nothnagel's Spec. Path. u. Ther., xviii, ii, p. 286. Vienna, 1898.

[31] Carnot. Paris Thesis, 1898.

[32] Flexner. Contributions to the Science of Medicine, Dedicated to Wm. H. Welch, M. D., p. 743. Baltimore, 1900.

tration separating islands of parenchyma. In places the gland substance is soft and of gray necrotic appearance. The splenic part is firm in consistence and at several points are areas of hemorrhagic infiltration. Microscopic examination of sections from the hemorrhagic duodenal part shows wide areas of necrosis implicating both lobular and interstitial tissue. The parenchymatous cells are hyaline and without nuclei. Copious hemorrhage has taken place into these areas and at the margin of intact tissue polynuclear leucocytes are numerous. Fibrin is abundant in the necrotic interlobular tissue. Where widespread destruction has not occurred there has been active proliferation of interstitial tissue replacing in part destroyed parenchyma and containing numerous red blood corpuscles and polynuclear leucocytes. The remaining acini are often separated by newly-formed interstitial tissue and there is the appearance of advanced chronic inflammation. In the splenic part of the gland foci of necrosis with hemorrhage occur and in small scattered areas there is newly-formed connective tissue.

Experiment 3.—After opening the duodenum 5 cc. of bile obtained from a second dog was injected into the pancreatic duct. Death followed within twenty hours. The peritoneal cavity contains several cubic centimetres of bloody fluid and the peritoneal surface has an irregularly distributed, deep red injection. The entire omentum is studded with conspicuous opaque white areas of fat necrosis, usually round, 1 to 1.5 mm. in diameter, and surrounded by a zone of injection. They are most abundant in the neighborhood of the spleen, where superficially and on section they occupy about one-half the exposed surface. In the mesentery of the duodenum near the pancreas they are numerous, but in the remainder of the mesentery of both large and small intestine they are sparcely scattered. Similar foci are present in the retroperitoneal fat and in the properitoneal fat below the diaphragm. The splenic arm and the upper half of the attached duodenal part of the pancreas are swollen and œdematous in appearance and the lobulations are separated by tissue infiltrated with blood. The cut surface has a mottled dull red and gray color, the interstitial tissue being hemorrhagic, while minute hemorrhages are in places seen within the lobular substance. The left lung is the seat of a mucopurulent bronchitis. A culture made from the peritoneal cavity remained sterile. A short bacillus was grown from the pancreas. Microscopical examination shows that the dull red areas of the pancreas represent foci of necrosis where the parenchymatous cells stain only with eosin and no longer contain nuclei. The blood-vessels here are widely dilated and abundant hemorrhage has frequently taken place. Polynuclear leucocytes are present but are not very numerous. Such an area of necrosis and hemorrhage is at times limited to the central part of a lobule group, while the acini further from the central duct are intact. The interstitial tissue particularly of the duodenal part of the gland has an œdematous appearance and contains red blood corpuscles, polynuclear leucocytes and fibrin.

Experiment 4.—By means of a sharp pointed needle 3 cc. of bile was withdrawn from the gall bladder and injected into the larger pancreatic duct. The animal was killed at the end of seven days. Upon the surface of the pancreas where it is in contact with the duodenum are a few sparcely scattered opaque white areas of small size. In the omentum near the gland are a few similar foci of necrosis. The pancreas is normal in consistence and no change is noted macroscopically. Microscopic examination shows the interstitial tissue of the splenic and duodenal parts of the gland moderately infiltrated in places with blood corpuscles, while here and there it is distended and has an œdematous appearance. The parenchyma is normal in the sections examined.

Experiment 5.—The operation previously described was repeated and 2.5 cc. of bile was withdrawn from the gall bladder and after opening the duodenum injected into the larger pancreatic duct. The dog was killed at the end of four days. The pancreas which is not adherent to the adjacent structures is firm in consistence and has throughout a reddish-gray color, but is nowhere hemorrhagic. On the surface of the duodenal part in contact with the duodenum are sparcely scattered opaque white areas of fat necrosis. Microscopic examination of a section from the duodenal part of the gland shows that newly-formed cellular connective tissue has in a small area replaced the glandular elements. Proliferation of cells has occurred in the adjacent interlobular tissue which contains in abundance red blood corpuscles, polynuclear leucocytes and fibrin.

Should bile enter the pancreas after occlusion of the distal end of the diverticulum of Vater, its only opportunity for escape would be by way of the lesser pancreatic duct. In order to reproduce this condition, in the following experiments the duodenum was not opened, but the duct was exposed where it approaches the intestine, ligated close to the duodenum and partially cut across. By means of a syringe with a blunt nozzle, bile was injected into the distal end of the duct which was then ligated.

Experiment 6.—Into the larger duct was injected 5 cc. of bile obtained by puncture from the dog's gall bladder. The animal died twenty-four hours later. The peritoneal cavity contains no excess of fluid. Opaque white areas of fat necrosis are numerous upon the surface of the duodenal part of the pancreas and in the immediately adjacent fat of the duodenal mesentery. Similar foci are present in both layers of the mesentery near the stomach and pancreas and in the fat in contact with the splenic part of the gland. The interstitial tissue of the duodenal part over an area near the orifice of the larger duct, 2.5 cm. in width, shows deep red hemorrhagic infiltration. The parenchyma throughout the gland is mottled, small dull red areas alternating with more normal gray yellow gland substance. This hemorrhagic appearance of the parenchyma is most marked in the duodenal part of the gland where there are homogeneous dull red areas of considerable extent. Both lungs contain extensive deep red areas which are fairly firm in consistence and exude very abundant frothy serum. Microscopic examination of all parts

of the pancreas shows the presence of numerous foci of necrosis. The gland cells have assumed a hyaline appearance and have lost their nuclei. The blood vessels in these areas are widely distended and at times there is abundant extravasation of red blood corpuscles. Polynuclear leucocytes in moderate number are seen between the necrotic cells. The interlobular tissue is in many places much distended, containing red blood corpuscles, polynuclear leucocytes and fibrin.

Experiment 7.—The operation already described was repeated and 3.7 cc. of bile obtained from the gall bladder of the same dog was injected into the larger duct. The animal was killed three days later. Upon the surface of that part of the pancreas which is in contact with the duodenum and in the fat immediately adjacent to the splenic part are a few opaque areas of necrosis. The pancreas is very firm throughout. On section the glandular lobules are found to be separated by septa of interstitial tissue which are firmer and thicker than usual and near the termination of the larger duct infiltrated with blood. In the duodenal and splenic parts of the gland microscopic examination demonstrates within the lobular tissue numerous small areas where newly-formed, very cellular interstitial tissue replaces groups of acini. The interlobular tissue is infiltrated with red blood corpuscles and often contains in great abundance polynuclear leucocytes and fibrin.

SYNOPSIS OF EXPERIMENTS.

I.—Duodenum Opened and Duct Injected.

	Amount of bile.	Mode of death.	Pancreas.	Fat.
No. 1	5cc.	Killed in 7 days.	Hemorrhagic inflammation and sclerosis.	Fat necrosis near pancreas.
No. 2	5cc.	Killed in 5 days.	Hemorrhagic inflammation and sclerosis.	Fat necrosis.
No. 3	5cc.	Died in 20 hours.	Hemorrhagic inflammation.	Extensive fat necrosis.
No. 4	3cc.	Killed in 7 days.	Slight hemorrhagic infiltration.	Slight fat necrosis.
No. 5	2.5cc.	Killed in 4 days.	Slight hemorrhagic infiltration and sclerosis.	Slight fat necrosis.

II.—Duct Opened, Injected and Ligated.

No. 6	5cc.	Died in 24 hours.	Hemorrhagic inflammation.	Fat necrosis.
No. 7	3.7cc.	Killed in 3 days.	Hemorrhagic inflammation and sclerosis.	Slight fat necrosis.

The injection of 5 cc. of bile into the pancreatic duct caused hemorrhagic inflammation of the gland in four dogs, two of which died within twenty-four hours after the operation. Death did not follow the use of smaller amounts and the changes produced in the organ were less wide spread and severe. In every case necrosis of the adjacent fat accompanied the lesion of the pancreas, and in the two instances in which death occurred spontaneously foci of necrosis were abundant and disseminated. In Experiment No. 1, though the entire splenic arm of the gland was the seat of an intense inflammatory reaction, coverslips and cultures demonstrated the absence of bacteria. The presence of bacteria in the pancreas of dog No. 2, which died twenty hours after the operation, is not surprising since the injection was made through the duodenal orifice of the duct.

Microscopic examination confirmed the diagnosis of hemorrhagic pancreatitis and demonstrated the identity of the experimental lesions with that which occurs in human cases. The injected bile first causes necrosis of the parenchymatous cells with which it comes into contact. They loose their nuclei and their protoplasm assumes a homogeneous hyaline appearance and stains deeply with eosin. The injurious action of the irritant upon the blood-vessels is manifested by the occurrence of hemorrhage into these necrotic areas. An inflammatory reaction now ensues and is characterized by the accumulation of polynuclear leucocytes and fibrin in the interstitial tissue and in the necrotic parenchyma. The necrotic material undergoes disintegration and a rapid new growth of interstitial fibrous tissue in part or wholly replaces it. Where death does not rapidly follow the primary effects of the operation opportunity is given for the occurrence of secondary changes in the gland. The experimental lesion is not in all cases so extensive as that recorded in the accompanying autopsy report. In these experiments a single injection of bile is made, while in the human case bile is repeatedly poured into the organ.

Conclusions.

(1) A small gall stone impacted in the diverticulum of Vater may occlude the common orifice of the bile duct and duct of Wirsung and convert them into a continuous closed channel. Bile enters the pancreas by way of the pancreatic duct and the pancreas becomes the seat of inflammatory changes characterized by necrosis of the parenchymatous cells, hemorrhage and the accumulation of inflammatory products. Anatomical peculiarities of the diverticulum of Vater do not permit this sequence of events in all individuals.

(2) Injection of bile into the pancreatic duct of dogs causes a necrotizing hemorrhagic inflammation of the pancreas resembling the human lesion, and like it accompanied by fat necrosis. Necrosis of the parenchymatous cells and hemorrhage represent the primary action of the bile; an inflammatory reaction rapidly follows.

(3) The frequent association of cholelithiasis with hemorrhagic and gangrenous pancreatitis is the result of impaction of gall stones at the orifice of the diverticulum of Vater and penetration of bile into the pancreas.

THE JOHN W. GARRETT INTERNATIONAL FELLOWSHIP.

It is gratifying to be able to announce that the John W. Garrett International Fellowship has been founded by William Johnston in connection with University College, Liverpool, in memory of the late John W. Garrett, of Baltimore, and former Trustee of this Hospital, with the title of the "John W. Garrett International Fellowship in Pathology and Physiology."

The Fellowship is to be open to members of Universities and Medical Schools in the United States, without, however, precluding the conferring of the Fellowship upon members of other foreign schools.

The Fellow is to be elected by the Faculty of University College, Liverpool, on the nomination of the Professors of Pathology and Physiology. He is elected for one year, but may be reappointed. He is required to devote himself to research in physiology or pathology and bacteriology, under the direction of the Professors of Physiology and Pathology. The work is to be done in the Thompson Yates Laboratories of University College, but by special permission from the Faculty the Fellow may pursue necessary investigations elsewhere. The expenses of all researches are to be met out of the funds of the laboratory.

NOTES ON NEW BOOKS.

Lehrbuch der Anatomie der Haustiere mit besonderer Berücksichtigung des Pferdes. An Stelle des in 1. und 2. von Leyh, in 3. und 4. von Franck, in 5. Auflage von Martin Herausgegebenen Handbuchs der Anatomie der Haustiere. Vollständig neu Bearbeitet. Von Dr. Paul Martin, professor an der Tierarzneischule in Zürich. (*Stuttgart: Verlag von Schickhardt & Ebner* (*Konrad Wittwer*), *1901.*) Price 40 Marks.

It is a pleasure for those interested in this subject to go through the new edition of the Leyh-Franck Anatomy, thoroughly revised, in fact rewritten, by Professor Martin. The scope of the work is so extensive and the treatment so compact, thorough and scientific that students of veterinary medicine (or any medical students) must rise far above the average in ability and in training to pursue this anatomy.

The work is divided into two large volumes, the first of which is devoted to general anatomy and embryology to the extent they underlie the systems of the body. Then the histology and microscopic anatomy of the organs follow. This arrangement of the general part makes it possible to consider phylogeny with ontogeny without causing confusion. In fact this is necessary. By this arrangement the first volume serves as a broad scientific basis for the second, thus giving a firm foundation upon which the systematic anatomy is easily united with the other morphological sciences.

The author includes with the discussion of the organs their histology and microscopic anatomy, for his experience as a teacher is that such treatment has always been welcomed by his students. In this direction the text is extensive enough and the illustrations sufficiently numerous to serve as a good foundation for these subdivisions of the main subjects.

The second volume is devoted to descriptive systematic anatomy. It is arranged to guide the student in the study of dissections.

All in all the work reminds one somewhat of Quain's Anatomy, or rather of Rauber's revision of it. The illustrations are numerous and excellent, the text is well written and clear, showing that the author is master of the subject.

That an Anatomy of this rank is in its sixth edition speaks much for veterinary education in Europe. Students with a training in anatomy sufficiently broad to grasp this work are raised far above the average veterinarian of America. Fortunately, we have two or three veterinary colleges in which the course in anatomy is up to the level of Martin, and we cordially recommend this book to them as well as to all others who are interested in the comparative anatomy of the domestic animals.

A Text-Book of Histology. By A. A. Böhm and N. von Davidoff. Edited by G. Carl Huber; translated by H. H. Cushing. (*Philadelphia: W. B. Saunders & Co., 1900.*)

It is a matter for congratulation that so good a book as Böhm and von Davidoff's Histology has been translated into English, and put within the reach of all American students of anatomy. It would seem at first sight that a book of this character written in German could be as easily and widely used as an English edition; but such is by no means the case. To the average student a foreign language forms a very considerable obstacle, and a good book written in German, for example, is not infrequently put aside for a less valuable English substitute. In editing an English version of what is one of the best short Histologies in any language, Dr. Huber has rendered a valuable service to both teachers and students; and in bringing this book to a certain extent up to date, he has made it a most valuable laboratory guide.

It is somewhat to be regretted that the editor did not in this work bring all the parts of the book equally in touch with the latest literature. Many of the descriptions seem to have been left as they were in the original, no regard being given to work which has been done since that edition was published. Some organs, on the other hand, are described in great detail, and fairly full references made to the original sources of information. An excellent account is given of the epithelial and connective tissues, and the addition of Dr. Huber's own work to the section on nervous tissues makes it an interesting and valuable article. The chapters on muscle and blood, however, might with advantage be much amplified. The lymph and thyroid glands also merit more attention than they receive. Very good descriptions are given of all the thoracic and abdominal viscera, especial attention being given in almost every case to the nerve supply. This influence of Huber's own work is felt in many of the chapters, and the detailed description of nerve endings in the various organs is a conspicuous feature of this edition of the book. The blood supply in most cases is much less fully described.

The illustrations are excellent throughout, and good judgment is shown in their selection. There are very few that could be omitted with advantage. Perhaps the same criticism, however, could be made of the figures as has been suggested concerning the text. Some chapters are excellently illustrated and others only indifferently so. This is hardly to be avoided in treating so large a subject in such a brief space.

The part which deals with special technique is one of the most valuable in the book. It is compiled with the greatest care and contains numerous methods which will be of very real assistance to laboratory workers. The methods of maceration and digestion of tissues will be found especially instructive in laboratory courses.

A good index and a list of the articles referred to in the text complete this excellent book, upon the appearance of which Dr. Huber is to be sincerely congratulated. It is without doubt one of the best brief text-books of Histology to be obtained at present.

J. B. MacCallum.

Hand Atlas of Human Anatomy. By Werner Spalteholz, Extraordinary Professor of Anatomy in the University and Custodian of the Anatomical Museum at Leipzig, with the advice of Wilhelm His, Professor of Anatomy in the University of Leipzig. Translated from the third German edition by Lewellys F. Barker, Professor of Anatomy in the University of Chicago, with a preface by Franklin P. Mall,

Professor of Anatomy in the Johns Hopkins University at Baltimore. Vol. I, Bones, Joints, Ligaments. Cloth, $3.50. Pages 235, figures 1-280. (*Leipzig: S. Hirzel; New York: G. Stechert.*)

Descriptive anatomy is essentially a study of form and of spacial relations. Pictures and models constitute the most satisfactory means of expressing these phenomena. Illustration is therefore a most important factor in anatomical study. Pictures showing the main anatomical conditions which the researches of centuries have revealed serve as the best guide in dissection; pictorial illustration is the best means of recording the work of this kind. The student should have good pictures to aid him in his task. He should sketch the results of his dissections in order to formulate clearly the ideas revealed to him by the work.

Anatomical illustration is an interesting subject. Before the beginning of the nineteenth century it was the habit of the anatomist to make a rough sketch of a dissected part. This sketch was then turned over to the engraver, who elaborated the drawing on wood or copper, eliminated its crudities and produced a fine picture. The effect of the engraver's imagination is most clearly seen perhaps in the plates that accompany the work of Versalius and the earlier anatomists. The eviscerated subject of the dissection may there often be seen smiling in the midst of a beautiful landscape. As a rule, parts of the body are shown out of their true positions in the body, often considerably distorted, in order to show the front and back of the same object in the same picture.

In the early part of this century the lithograph was introduced as means of illustration. Here too the hand of the lithographer could be relied upon to correct and elaborate original sketches. Many of the plates made by this process are very beautiful, though here, as in the case of the engraving, there has always been the danger of error owing to the elaboration being made from the drawing, not from the object.

Of recent years the attempt has been made more and more to picture the various parts of the body in their true positions relative to the body contour, to picture the deeper muscles, for instance, as they appear when the superficial muscles have been removed, to show nerves and arteries by representing parts covering them as cut away instead of pulled aside. This has necessitated much more care in the preparation of the parts to be pictured; it has necessitated much more skill on the part of the artist who attempts to depict the parts in their true relations and proportions. Unless the anatomist is an artist of unusual skill and ability he must call in the services of a trained artist if he wishes to illustrate his work well.

This necessity is rendered still more imperative by the modern methods of making plates by the aid of photography. The anatomist cannot hand over a rude sketch to the publisher who desires that the cheaper photograph methods of reproduction be used. The crudities of the sketch appear in the reproduction with startling distinctness. The reproduction appears less well finished instead of better finished than the original. The trained artist who can make drawings that can stand mechanical reproduction has become a necessity. In many ways this is a great gain. It is far better that the elaboration should be made from the object itself, as is the case when an artist is employed, rather than from a sketch, as was the case in the old days of engravings.

Good pictures, moreover, are seldom possible without the aid of a constructive imagination. Anatomical pictures reproduced from photographs of dissections are with few exceptions barbaric in their crudity. Photography alone can be depended upon only when the object pictured is extremely simple or when the very greatest care is taken in making the dissection and the photograph is afterwards carefully retouched. Rüdinger's beautiful Nerve Atlas shows with what success this may be done.

In the Atlas before us modern conventional methods of illustration have been used, but they have been used with a perfection not hitherto seen in text-books of human anatomy. The drawings have been made by skilled artists and for the most part from careful dissections especially made for the purpose. Wash-drawings reproduced in half-tone are used to illustrate detailed structures and outline drawings are freely used for the purpose of pointing out relations. In illustrating the ligaments the bones are toned yellow for contrast. Colors are also used with effect in the volume on the muscles and blood-vessels which has appeared in German but has not yet been translated into English.

Spalteholz is well acquainted not only with the literature of anatomy but also with practical dissecting. His experience has led him to choose points of view both striking and instructive. Throughout, the attempt has been made to show things in their true relations.

In the volume before us (Vol. I, Bones, Ligaments and Joints) there is a preface by Prof. Mall in which the value of pictures to the student of anatomy is emphasized, and one by the author in which the general scope of the work is set forth. We could wish that Spalteholz had authorized the translation of his very excellent preface to the German edition. The English of the preface prepared for the translation is far from idiomatic.

The points illustrated in the various pictures are designated by printing their Latin title in full at the margin of each figure.

The bones of the skull are first depicted, several views of each bone being given in order that all the main points may be illustrated. The method of showing the relations of several of the bones is particularly happy. An individual bone, for instance the ethmoid, is drawn carefully in detail. The neighboring bones are drawn in simple outline. Following the illustrations of the individual bones several fine pictures are given of the skull as a whole, and of the chief cavities of the skull; the vertebræ and ribs and the bones of the limbs are then taken up in detail. A very good picture of the skeleton of the thorax is given. On outline drawings muscle attachments are indicated. The section on the ligaments is very satisfactory and is much more extensive than is common in the text-books. The internal architecture of the bones is shown in several special drawings.

Nomenclature is another most important consideration in the study of anatomy. The great wealth of detail which four centuries of earnest work has brought to light concerning the structure of the human body has been accompanied by an even greater mass of names. Investigators who have found nothing new or who have rediscovered facts already known have not hesitated to coin new terms until descriptive anatomy fairly groans under the load of terminology which rests on its shoulders. A great advance was made by the Anatomissche Gesellschaft at their meeting in Basel in 1895, when they adopted a list of descriptive terms which tend greatly to simplify the subject (His: Supplementband zur Anat. Abtheilung des Archiv f. Anatomie u. Physiologie, 1895).

The "New Nomenclature" has been used systematically throughout the book with a few unimportant exceptions. We believe that it is a mistake, however, to give a Latin name to every nook and corner of the human body. The more definite structures of the human body, like the bones, the main muscles, the larger arteries, veins and nerves and similar structures, are best designated by a specific name. Most of these terms have been derived from the Latin and by usage have become embodied in the various modern languages, sometimes unchanged, sometimes with slight alteration. Thus clavicle, humerus, femur, biceps, are all words in more or less common use in English. We think it is a very grave mistake, a relic of unprogressive scholasticism, to make use of Latin when terms are used to

describe as well as designate various definite structures of this nature. In the description of the frontal bone we can see no possible advantage in an English book in writing "In the medial part of the margo supraorbit. there is often a shallow notch, *incisura frontalis* (rarely a *foramen frontale*) (for the a. frontalis; r. frontal. n. frontal.) and lateralward from this a *foramen supraorbitale* or an *incisura supraorbitalis* (for the a. supraorbit.; n. supraorbit.) the anterior convex surface, *facies frontalis*"—etc. This great mass of descriptive Latin terminology merely serves to confuse the student and to take his mind from the essential to the unessential, from the object to the descriptive term. An absurd amount of detailed acquaintance with dissociated parts of the body is at present demanded of the medical student. It is a pity to continue to add a mass of Latin to his burden at the very time that he is beginning to be freed from the shackles of therapeutical botany and its barbarisms.

The main object of an anatomical atlas is to furnish good, clear pictures of the various parts of the body. The text is of minor importance and its chief function is to point out the relations revealed by the pictures and the relations of the pictures to one another. This function is admirably served by the text accompanying the illustrations in Spalteholz's atlas. Such a text confessedly does not take the place of a good text-book. In addition to the atlas the student needs a book in which the dry subject of descriptive anatomy is brightened and enriched by treating of the various parts of the body in their relation to physiological phenomena, to embryology and to comparative anatomy. Gegenbauer's Anatomie des Menschen is an admirable example of such a text-book in which the side of embryology and comparative anatomy is especially emphasized.

The English reading student of medicine is fortunate in having had translated for his use this excellent Atlas of Spalteholz. He is especially fortunate in having a translation that has been made by a man of the marked ability of Professor Barker. Professor Barker has been very true to the original text and yet has been able to give us a text exceptionally smooth for a translation so literal.

The printing of the book shows the care and nicety that distinguishes the firm of Hirzel.

We could wish that there were more pictures in this volume in which the skeleton as an organic whole were shown. For instance, not only is there no picture of the skeleton as a whole, but there are none of the limbs as a whole. It is not enough, we think, to give in an atlas merely the hand, the forearm and the humerus as separate parts.

In comparing the illustrations of this Atlas with text-books of a similar scope we find that that of Toldt is the one most similar to it in scope. The beautifully illustrated text-books of Sappey and of Testut are much more expensive and have a different function to perform. Compared with Toldt's Atlas we find the pictures in Spalteholz are more delicate in detail and less diagrammatic. On the other hand, the pictures in Toldt are made sharp and vigorous, owing to the dependence on lines rather than on light and shade. Toldt also has done well in showing the organs in relation to larger areas of the body. The superiority of the pictures in Spalteholz lies in their natural tone.

Charles Russell Bardeen.

BOOKS RECEIVED.

A Practical Treatise on Materia Medica and Therapeutics. With Especial Reference to the Clinical Application of Drugs. By John V. Shoemaker, M. D., LL. D. Fifth edition, thoroughly revised. (Students' Edition.) 1900. 8vo. 766 pages. F. A. Davis Company, Philadelphia, New York, Chicago.

Medical and Surgical Reports of the Boston City Hospital. Eleventh Series. Edited by Herbert L. Burrell, M. D., W. T. Councilman, M. D., and Charles F. Withington, M. D. 1900. 8vo. 254 pages. Published by the Trustees, Boston.

American Text-Book of Physiology. Edited by William H. Howell, Ph. D., M. D. Second edition, revised. Volume II. 1901. 4to. 553 pages. W. B. Saunders and Company, Philadelphia and London.

Abstract of Report on the Origin and Spread of Typhoid Fever in U. S. Military Camps During the Spanish War of 1898. By Walter Reed, M. D., Victor C. Vaughan, M. D., and Edward O. Shakespeare, M. D. 1900. 8vo. 239 pages. Government Printing Office, Washington.

State of New York. State Commission in Lunacy. Eleventh Annual Report, October 1, 1898, to September 30, 1899. Two volumes. 8vo. 1900. Albany.

A Text-Book of Pathology. By Alfred Stengel, M. D. Third edition, revised. With 372 illustrations. 1900. 8vo. 873 pages. W. B. Saunders and Company, Philadelphia and London.

Disinfection and Disinfectants. A Treatise upon the Best Known Disinfectants, their Use in the Destruction of Disease Germs, with Special Instruction for their Application in the Commonly Recognized Infectious and Contagious Diseases. By H. M. Bracken, M. D. 1900. 16mo. 91 pages. Published by the Trade Periodical Company, Chicago.

Diseases of the Heart: their Diagnosis and Treatment. By Albert Abrams, A. M., M. D. (Heidelberg), F. R. M. S. 1900. 12mo. 170 pages. G. P. Engelhard and Company, Chicago.

Urinary Diagnosis and Treatment. By John W. Wainwright, M. D. 1900. 12mo. 138 pages. G. P. Engelhard and Company, Chicago.

Transactions of the Congress of American Physicians and Surgeons. Fifth Triennial Session held at Washington, D. C., May first and second, 1900. 8vo. xlix + 119 pages. Published by the Congress, New Haven, Conn.

Ringworm in the Light of Recent Research. Pathology—Treatment—Prophylaxis. By Malcolm Morris. With twenty-two micro-photographs and one coloured plate. 1898. 8vo. 142 pages. Cassell and Company, Limited. London, Paris and Melbourne.

The Surgical Treatment of Congenital and Pathological Disfigurements of the Face. Abstract of the Mütter Lectures of the College of Physicians of Philadelphia for 1900. By John B. Roberts, A. M., M. D. 8vo. 53 pages. 1900. The Philadelphia Medical Publishing Company, Philadelphia.

Thirty-first Annual Report of the State Board of Health of Massachusetts. 1900. 8vo. lvii + 812 pages. Wright and Potter Printing Co., Boston.

Transactions of the American Orthopedic Association. Fourteenth session held at Washington, D. C., May 1, 2 and 3, 1900. Volume XIII. 8vo. xxviii + 340 pages. 1900. Published by the Association, Philadelphia.

Transactions of the American Gynecological Society. Volume 25. For the year 1900. 8vo. xlvii + 454 pages. Philadelphia.

The Tale of a Field Hospital. By Frederick Treves. With fourteen illustrations from original photographs. 1900. 12mo. 109 pages. Cassell and Company, Limited. London, Paris, New York and Melbourne.

A Guide to the Instruments and Appliances Required in Various Operations. By A. W. Mayo Robson, F. R. C. S. Second Edition. 1900. 24. 62 pages. Cassell and Company, Limited. London, Paris, New York and Melbourne.

Tropical Diseases. A Manual of the Diseases of Warm Climates. By Patrick Manson, C. M. G., M. D., LL. D. (Aberd.) Revised and enlarged edition. With 114 illustrations and two coloured plates. 1900. 12mo. xx + 684 pages. Cassell and Company, Limited. London, Paris, New York and Melbourne.

Diseases of the Tongue. By Henry T. Butlin, F. R. C. S., D. C. L., and Walter G. Spencer, M. S., M. B. (Lond.), F. R. C. S. Illustrated with eight chromo-lithographs and thirty-six engravings. 1900. 8vo. xii + 475 pages. Cassell and Company, Limited. London, Paris, New York and Melbourne.

Report of the Surgeon-General of the Army to the Secretary of War. For the Fiscal Year ended June 30, 1900. 8vo. 411 pages. 1900. Government Printing Office, Washington.

Operative and Practical Surgery: For the Use of Students and Practitioners. By Thomas Carwardine, M. S. (Lond.), F. R. C. S. With 550 illustrations, most of which are original drawings by the author. 1900. 8vo. xx + 661 pages. John Wright and Company, Bristol.

The American Year-Book of Medicine and Surgery. Collected and arranged with critical editorial comments by S. W. Abbott, M. D., A. Church, M. D., *et al.* Under the general editorial charge of George M. Gould, M. D. Two volumes. 1901. 8vo. W. B. Saunders and Company, Philadelphia and London.

Golden Rules of Skin Practice. By David Walsh, M. D. Edin. [1900] 32mo. 102 pages. "Golden Rules" Series. No. viii. John Wright and Company, Bristol. Simpkin, Marshall, Hamilton, Kent & Co., Limited, London.

Transactions of the Clinical Society of London. Volume the Thirty-third. 1900. 8vo. xlix + 272 pages. Longmans, Green and Company, London.

A Text-Book of Histology, Including Microscopic Technic. By A. A. Böhm, M. D., and M. von Davidoff, M. D. Edited, with Extensive Additions to both Text and Illustrations by G. Carl Huber, M. D. Authorized translation from the second revised German edition by Herbert H. Cushing, M. D. 1900. 8vo. 501 pages. W. B. Saunders and Company, Philadelphia.

Introduction to the Study of Medicine. By G. H. Roger. Authorized translation by M. S. Gabriel, M. D. With Additions by the Author. 1901. 8vo. 545 pages. D. Appleton and Company, New York.

Panama and the Sierras, A Doctor's Wander Days. By G. Frank Lydston, M. D. Illustrated from the Author's Original Photographs. 1900. 12mo. 283 pages. The Riverton Press, Chicago.

Hypnotism. A Complete System of Method, Application and Use, Prepared for the Self-Instruction of the Medical Profession. By L. W. De Laurence. Illustrated. 1901. 12mo. 256 pages. The Henneberry Company, Chicago.

A Text-Book of Diseases of the Nose and Throat. By D. Braden Kyle, M. D. With 175 illustrations, 23 of them in colors. Second Edition. 1900. 8vo. 646 pages. W. B. Saunders and Company, Philadelphia.

The Treatment of Fractures. By Charles Locke Scudder, M. D., Assisted by Frederic J. Cotton, M. D. Second edition, revised. With 611 illustrations. 1901. 8vo. 457 pages. W. B. Saunders and Company, Philadelphia and London.

Transactions of the College of Physicians of Philadelphia. Third Series. Volume the Twenty-second. 1900. 8vo. lvi + 282 pages. Printed for the College, Philadelphia.

The Practice of Medicine. A Text-Book for Practitioners and Students, with Special Reference to Diagnosis and Treatment. By James Tyson, M. D. Second edition, thoroughly revised and in parts rewritten. With 127 illustrations, including colored plates. 1900. 8vo. 1222 pages. P. Blakiston's Son and Co., Philadelphia.

A Text-Book of Practical Obstetrics. By Egbert H. Grandin, M. D., with the collaboration of George W. Jarman, M. D. Third edition, revised and enlarged. Illustrated with fifty-two full-page photographic plates and one hundred and five illustrations in the text. 1900. 8vo. 511 pages. F. A. Davis Company, Philadelphia, New York, Chicago.

Obstetric and Gynecologic Nursing. By Edward P. Davis, A. M., M. D. Illustrated. 1901. 12mo. 402 pages. W. B. Saunders and Company, Philadelphia and London.

A Medico-Legal Manual. By William W. Keysor. 1901. 12mo. 316 pages. Omaha.

A Pilgrimage: or the Sunshine and Shadows of the Physician. By William Lane Lowder, B. S., M. D. 1897. 24mo. vi + 190 pages. Louisville, Kentucky.

Report Relating to the Registration of Births, Marriages and Deaths in the Province of Ontario for the year ending 31st December, 1899. Printed by order of the Legislative Assembly of Ontario. 8vo. 1901. 49 + ccxlii pages. L. K. Cameron, Toronto.

3500 Questions on Medical Subjects Arranged for Self-Examination. With the proper references to standard works in which the correct replies will be found. Third edition, enlarged. 1901. 32mo. 230 pages. P. Blakiston's Son and Company, Philadelphia.

Human Placentation. An Account of the Changes in the Uterine Mucosa and in the Attached Fetal Structures During Pregnancy. By J. Clarence Webster, B. A., M. D. (Edin.), F. R. C. P. E., F. R. S. E. With 233 illustrations. 1901. 4to. 126 pages. W. T. Keener and Company, Chicago.

A Text-Book of Gynecology. Edited by Charles A. L. Reed, A. M., M. D. Illustrated by R. J. Hopkins. 1901. 8vo. xxv + 900 pages. D. Appleton and Company, New York.

Nursing Ethics: For Hospital and Private Use. By Isabel Hampton Robb. 1901. 12mo. 273 pages. J. B. Savage, Cleveland.

The Medical Annual: A Year-Book of Treatment and Practitioner's Index. Nineteenth Year. 1901. 12mo. lxxx + 847 pages. John Wright & Co., Bristol. Simpkin, Marshall, Hamilton, Kent & Co., Ld., London.

Anatomical Atlas of Obstetrics with Special Reference to Diagnosis and Treatment. By Dr. Oskar Schaeffer. Authorized translation from the second revised German edition. Edited by J. Clifton Edgar, A. M., M. D. With 122 Figures on 56 Lithographic Plates, and 38 other Illustrations. (Saunders' Medical Hand-Atlases.) 1901. 12mo. 315 pages. W. B. Saunders & Company, Philadelphia and London.

Atlas of the Nervous System, Including an Epitome of the Anatomy, Pathology, and Treatment. By Dr. Christfried Jakob. With a preface by Prof. Dr. Ad. v. Strümpell. Authorized translation from the second revised German edition. Edited by Edward D. Fisher, M. D. With 112 Colored Lithographic Figures and 139 other Illustrations, many of them in Colors. (Saunders' Medical Hand-Atlases.) 1901. 12mo. 218 pages. W. B. Saunders and Company, Philadelphia and London.

Uterine Fibromyomata. Their Pathology, Diagnosis, and Treatment. By E. Stanmore Bishop, F. R. C. S., Eng. With 49 Illustrations. 1901. 8vo. xii + 323 pages. P. Blakiston's Son and Company, Philadelphia.

A Text-Book of the Practice of Medicine. By Dr. Hermann Eichhorst. Authorized translation from the German. Edited by Augustus A. Eshner, M. D. Two Volumes. 1901. 8vo. W. B. Saunders & Company, Philadelphia and London.

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In the methods of instruction especial emphasis is laid upon practical work in the Laboratories and in the Dispensary and Wards of the Hospital. While the aim of the School is primarily to train practitioners of medicine and surgery, it is recognized that the medical art should rest upon a suitable preliminary education and upon thorough training in the medical sciences. The first two years of the course are devoted mainly to practical work, combined with demonstrations, recitations and, when deemed necessary, lectures, in the Laboratories of Anatomy, Physiology, Physiological Chemistry, Pharmacology and Toxicology, Pathology and Bacteriology. During the last two years the student is given abundant opportunity for the personal study of cases of disease, his time being spent largely in the Hospital Wards and Dispensary and in the Clinical Laboratories. Especially advantageous for thorough clinical training are the arrangements by which the students, divided into groups, engage in practical work in the Dispensary, and throughout the fourth year serve as clinical clerks and surgical dressers in the wards of the Hospital.

REQUIREMENTS FOR ADMISSION.

As candidates for the degree of Doctor of Medicine the school receives:

1. Those who have satisfactorily completed the Chemical-Biological course which leads to the A. B. degree in this university.

2. Graduates of approved colleges or scientific schools who can furnish evidence: (a) That they have acquaintance with Latin and a good reading knowledge of French and German; (b) That they have such knowledge of physics, chemistry, and biology as is imparted by the regular minor courses given in these subjects in this university.

The phrase "a minor course," as here employed, means a course that requires a year for its completion. In physics, four class-room exercises and three hours a week in the laboratory are required; in chemistry and biology, four class-room exercises and five hours a week in the laboratory in each subject.

3. Those who give evidence by examination that they possess the general education implied by a degree in arts or in science from an approved college or scientific school, and the knowledge of French, German, Latin, physics, chemistry, and biology above indicated.

Applicants for admission will receive blanks to be filled out relating to their previous courses of study.

They are required to furnish certificates from officers of the college or scientific schools where they have studied, as to the courses pursued in physics, chemistry and biology. If such certificates are satisfactory, no examination in these subjects will be required from those who possess a degree in arts or science from an approved college or scientific school.

Candidates who have not received a degree in arts or in science from an approved college or scientific school will be required (1) to pass, at the beginning of the session in October, the matriculation examination for admission to the collegiate department of the Johns Hopkins University, (2) then to pass examinations equivalent to those taken by students completing the Chemical-Biological course which leads to the A. B. degree in this University, and (3) to furnish satisfactory certificates that they have had the requisite laboratory training as specified above. It is expected that only in very rare instances will applicants who do not possess a degree in arts or science be able to meet these requirements for admission.

Hearers and special workers, not candidates for a degree, will be received at the discretion of the Faculty.

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Applicants for admission to advanced standing must furnish evidence (1) that the foregoing terms of admission as regards preliminary training have been fulfilled, (2) that courses equivalent in kind and amount to those given here, preceding that year of the course for admission to which application is made, have been satisfactorily completed, and (3) must pass examinations at the beginning of the session in October in all the subjects that have been already pursued by the class to which admission is sought. Certificates of standing elsewhere cannot be accepted in place of these examinations.

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Since the opening of the Johns Hopkins Hospital in 1889, courses of instruction have been offered to graduates in medicine. The attendance upon these courses has steadily increased with each succeeding year and indicates gratifying appreciation of the special advantages here afforded. With the completed organization of the Medical School, it was found necessary to give the courses intended especially for physicians at a later period of the academic year than that hitherto selected. It is, however, believed that the period now chosen for this purpose is more convenient for the majority of those desiring to take the courses than the former one. The special courses of instruction for graduates in medicine are now given annually during the months of May and June. During April there is a preliminary course in Normal Histology. These courses are in Pathology, Bacteriology, Clinical Microscopy, General Medicine, Surgery, Gynecology, Dermatology, Diseases of Children, Diseases of the Nervous System, Genito-Urinary Diseases, Laryngology and Rhinology, and Ophthalmology and Otology. The instruction is intended to meet the requirements of practitioners of medicine, and is almost wholly of a practical character. It includes laboratory courses, demonstrations, bedside teaching, and clinical instruction in the wards, dispensary, amphitheatre, and operating-rooms of the Hospital. These courses are open to those who have taken a medical degree and who give evidence satisfactory to the several instructors that they are prepared to profit by the opportunities here offered. The number of students who can be accommodated in some of the practical courses is necessarily limited. For these the places are assigned according to the date of application.

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